



(19)

Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 625 633 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
15.03.2000 Bulletin 2000/11

(51) Int Cl.7: **B01D 53/04, F01N 3/08**

(21) Application number: **94901035.9**

(86) International application number:
PCT/JP93/01764

(22) Date of filing: **03.12.1993**

(87) International publication number:
WO 94/12778 (09.06.1994 Gazette 1994/13)

(54) EXHAUST GAS CLEANING APPARATUS FOR INTERNAL COMBUSTION ENGINES**ABGASREINIGUNGSGERAET FUER BRENNKRAFTMASCHINEN****EPURATEUR DE GAZ D'ECHAPPEMENT POUR MOTEURS A COMBUSTION INTERNE**

(84) Designated Contracting States:
DE FR GB

- **IGUCHI, Satoshi**
1, Toyota-cho, Toyota-shi, Aichi (JP)
- **NAKANISHI, Kiyoshi**
1, Toyota-cho, Toyota-shi, Aichi (JP)
- **KATOH, Kenji**
1, Toyota-cho, Toyota-shi, Aichi (JP)

(30) Priority: **03.12.1992 JP 32427992**
02.02.1993 JP 1560293
10.06.1993 JP 13858693

(74) Representative: **Tiedtke, Harro, Dipl.-Ing. et al**
Patentanwaltsbüro
Tiedtke-Bühlung-Kinne & Partner
Bavariaring 4
80336 München (DE)

(43) Date of publication of application:
23.11.1994 Bulletin 1994/47

(56) References cited:

(73) Proprietor: **TOYOTA JIDOSHA KABUSHIKI**
KAISHA
Aichi-ken 471-8571 (JP)

JP-A- 1 030 643	JP-A- 2 149 714
JP-A- 2 149 715	JP-A- 3 124 909
JP-A- 4 171 215	JP-A- 5 076 771
JP-A- 53 115 687	JP-A- 60 182 325
JP-B- 1 056 816	JP-U- 62 126 508

(72) Inventors:

- **TAKEHIMA, Shinichi**
1, Toyota-cho, Toyota-shi, Aichi (JP)
- **SETO, Satomi**
1, Toyota-cho, Toyota-shi, Aichi (JP)
- **TANAKA, Toshiaki**
1, Toyota-cho, Toyota-shi, Aichi (JP)

EP 0 625 633 B1

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

[0001] The present invention relates to a purification process for purifying exhaust gas of an internal combustion engine.

BACKGROUND ART

[0002] The present applicant has already proposed an internal combustion engine in which a lean air-fuel mixture is burned, in which internal combustion engine an NO_x absorbent which absorbs the NO_x when the air-fuel ratio of an inflowing exhaust gas is lean and releases the absorbed NO_x when the oxygen concentration in the inflowing exhaust gas is lowered is arranged in an engine exhaust passage; the NO_x generated when the lean air-fuel mixture is burned is absorbed by the NO_x absorbent before the NO_x absorption capability of the NO_x absorbent is saturated, the air-fuel ratio of the inflowing exhaust gas to the NO_x absorbent is temporarily made rich so that the NO_x absorbent is made to release the NO_x and, at the same time, the released NO_x is reduced EP-A-0.560.991 published 22.09.93.

[0003] However, the fuel and the lubrication oil of the engine contain sulfur, and therefore SO_x is contained in the exhaust gas. Accordingly, in this internal combustion engine, this SO_x is also absorbed into the NO_x absorbent together with the NO_x. However, this SO_x is not released from the NO_x absorbent even if the air-fuel ratio of the inflowing exhaust gas to the NO_x absorbent is made rich, and accordingly the amount of SO_x in the NO_x absorbent is gradually increased. However, when the amount of SO_x in the NO_x absorbent is increased, the amount of the NO_x that can be absorbed by the NO_x absorbent is gradually lowered, and finally the NO_x absorbent becomes no longer able to absorb almost any NO_x. Therefore, the present applicant has already proposed an internal combustion engine in which a sulfur trap is provided in the engine exhaust passage at the upstream side of the NO_x absorbent, and the SO_x contained in the exhaust gas is caught by this sulfur trap EP-A-0.582.917, published 16.02.94. In this internal combustion engine, the SO_x discharged from the engine is caught by the sulfur trap, and therefore only the NO_x is absorbed into the NO_x absorbent.

[0004] However, in this internal combustion engine, the SO_x caught by the sulfur trap is continuously being caught in the sulfur trap without being released from the sulfur trap even if the air-fuel ratio of the exhaust gas flowing into the sulfur trap is made rich. Accordingly, the amount of the SO_x caught by the sulfur trap is gradually increased. When the SO_x catching capability of the sulfur trap is saturated, the SO_x passes through the sulfur trap, and therefore there arises a problem in that the SO_x is absorbed into the NO_x absorbent and gradually accumulates in the NO_x absorbent.

DISCLOSURE OF THE INVENTION

[0005] The object underlying the invention is to provide a purification process for purifying exhaust gas of an internal combustion engine provided with an NO_x adsorbent and an SO_x adsorbent, both arranged in the exhaust passage of the internal combustion engine, wherein the SO_x adsorbent is arranged upstream of the NO_x adsorbent. Further, an exhaust purification device for conducting the process should be provided.

[0006] This object is solved by the features of claim 1. According to the invention, an air-fuel ratio control means usually maintains the air-fuel ratio of the exhaust gas flowing into said SO_x adsorbent lean and makes the air-fuel ratio of the exhaust gas flowing into said SO_x adsorbent rich, when the SO_x should be released from the SO_x adsorbent to ensure that the SO_x adsorbent is capable of absorbing SO_x during the usual operation conditions.

[0007] In the following description advantageous embodiments of the invention are described.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Figure 1 is an overall view of an internal combustion engine; Fig. 2 is a view showing a map of a basic fuel injection time; Fig. 3 is a view showing a change of a correction coefficient K; Fig. 4 is a graph schematically showing a concentration of unburnt HC and CO and oxygen in an exhaust gas discharged from the engine; Figs. 5A and 5B are views for explaining an NO_x absorption and releasing function; Fig. 6 is a view showing a releasing timing of the NO_x and SO_x; Fig. 7 is a flow chart showing an interruption routine; Fig. 8 is a flow chart for calculating a fuel injection time TAU; Fig. 9 is an overall view showing another embodiment of the internal combustion engine; Fig. 10 is an overall view showing still another embodiment of the internal combustion engine; Fig. 11 is a flow chart for performing the NO_x releasing processing; Fig. 12 is an overall view showing further another embodiment of the internal combustion engine; Fig. 13 is a view showing a releasing characteristic of the SO_x; Fig. 14 is a view showing the SO_x and NO_x releasing timing; Fig. 15 is a view showing a rich control at the time of releasing of NO_x; Figs. 16A to 16C are views showing a relationship between various types of parameters and an exhaust gas temperature; Fig. 17 is a view showing the rich control at the time of releasing of SO_x; Figs. 18A to 18D are views showing a relationship between various types of parameters and the exhaust gas temperature; Fig. 19 is a view showing a map of the exhaust gas temperature; Fig. 20 and 21 are flow charts for calculating the correction coefficient KK; Fig. 22 is a flow chart for calculating the fuel injection time TAU; Fig. 23 is an overall view showing still another embodiment of the internal combustion engine; Fig. 24 is a view showing a map of the basic fuel injection time; Fig. 25 is a view showing the

correction coefficient K; Figs. 26A and 26B are graphs showing an NO_x releasing rate and an SO_x releasing rate; Figs. 27A and 27B are graphs showing a cumulative release of the NO_x and SO_x ; Fig. 28 is a timing chart of an SO_x releasing control; Fig. 29 is a timing chart of an SO_x and NO_x releasing control; Fig. 30 is a timing chart of the SO_x and NO_x releasing control; Fig. 31 is a timing chart showing the change of the air-fuel ratio of the NO_x and SO_x releasing control, etc.; Figs. 32A to 32D are flow charts of a flag switch valve control; Fig. 33 is a view showing the map of the exhaust gas temperature T; Fig. 34 is a flow chart for calculating the fuel injection time TAU; Figs. 35A to 35D are flow charts of the flag switch valve control; Fig. 36 is a flow chart for calculating the fuel injection time TAU; Figs. 37A to 37D are flow charts of the flag switch valve control; Fig. 38 is a flow chart for calculating the fuel injection time TAU; Figs. 39A to 39D are flow charts of the flag switch valve control; and Fig. 40 is a flow chart for calculating the fuel injection time TAU.

BEST MODE FOR WORKING THE INVENTION

[0009] Figure 1 shows a case where the present invention is applied to a gasoline engine.

[0010] Referring to Fig. 1, 1 denotes an engine body; 2, a piston; 3, a combustion chamber; 4, a spark plug; 5, an intake valve; 6, an intake port; 7, an exhaust valve; and 8, an exhaust port; respectively. The intake port 6 is connected via a corresponding branch pipe 9 to a surge tank 10, and fuel injectors 11 for injecting the fuel toward inside the intake port 6 are attached to the respective branch pipes 9, respectively. The surge tank 10 is connected via an intake duct 12 and an air flow meter 13 to an air cleaner 14, and a throttle valve 15 is arranged in the intake duct 12. On the other hand, the exhaust port 8 is connected via the exhaust manifold 16 and the exhaust pipe 17 to a casing 20 accommodating an SO_x absorbent 18 and an NO_x absorbent 19. The SO_x absorbent 18 is arranged on the upstream side of the NO_x absorbent 19. In the embodiment shown in Fig. 1, the SO_x absorbent 18 and the NO_x absorbent 19 are integrally formed using one monolithic carrier made of for example alumina.

[0011] An electronic control unit 30 comprises a digital computer and is provided with a ROM (read only memory) 32, a RAM (random access memory) 33, a CPU (microprocessor) 34, an input port 35, and an output port 36, which are mutually connected by a bidirectional bus 31. The air flow meter 13 generates an output voltage in proportion to the intake air amount, and this output voltage is input via an AD converter 37 to the input port 35. Also, a rotational speed sensor 21 generating an output pulse expressing the engine rotational speed is connected to the input port 35. On the other hand, the output port 36 is connected via a corresponding drive circuit 38 to the spark plug 4 and the fuel injector 11, respectively.

[0012] In the internal combustion engine shown in Fig. 1, the fuel injection time TAU is calculated based on for example the following equation:

5

$$\text{TAU} = \text{TP} \cdot K$$

[0013] Here, TP indicates the basic fuel injection time; and K indicates the correction coefficient. The basic fuel injection time indicates a fuel injection time necessary for making the air-fuel ratio of the air-fuel mixture fed into the engine cylinder the stoichiometric air-fuel ratio. This basic fuel injection time TP is found in advance by experiments and stored in advance in the ROM 32 in the form of a map as shown in Fig. 2 as a function of the engine load Q/N (intake air amount Q/engine rotational speed N) and the engine rotational speed N. The correction coefficient K is a coefficient for controlling the air-fuel ratio of the air-fuel mixture fed into the engine cylinder, and if K = 1.0, the air-fuel mixture fed into the engine cylinder becomes the stoichiometric air-fuel ratio. Contrary to this, when K becomes smaller than 1.0, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder becomes larger than the stoichiometric air-fuel ratio, that is, becomes lean, while when K becomes larger than 1.0, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder becomes smaller than the stoichiometric air-fuel ratio, that is, becomes rich.

[0014] This correction coefficient K is controlled in accordance with the operating state of the engine. Figure 3 shows one embodiment of control of the correction coefficient K. In the embodiment shown in Fig. 3, during a warm-up operation, the correction coefficient K is gradually lowered as the engine coolant temperature becomes higher. When the warm up is completed, the correction coefficient K is maintained at a constant value smaller than 1.0, that is, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is maintained lean. Subsequently, when an acceleration operation is carried out, the correction coefficient K is made for example 1.0, that is, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made the stoichiometric air-fuel ratio. When a full load operation is carried out, the correction coefficient K is made larger than 1.0, that is, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made rich. As seen from Fig. 3, in an embodiment shown in Fig. 3, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is maintained at the constant lean air-fuel ratio except at the time of a warm-up operation, the time of an acceleration operation, and at the time of a full load operation. Accordingly in most of the engine operating regions, a lean air-fuel mixture will be burned.

[0015] Figure 4 schematically shows the concentration of representative components in the exhaust gas discharged from the combustion chamber 3. As seen from Fig. 4, the concentration of the unburnt HC and CO in the exhaust gas discharged from the combustion

chamber 3 is increased as the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes richer, while the concentration of the oxygen O₂ in the exhaust gas discharged from the combustion chamber 3 is increased as the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes leaner.

[0016] The NO_x absorbent 19 accommodated in the casing 20 uses for example alumina as the carrier. This carrier carries at least one substance selected from alkali metals such as potassium K, sodium Na, and cesium Cs, alkali earths such as barium Ba and calcium Ca, and rare earths such as lanthanum La and yttrium Y and a precious metal such as platinum Pt. Note that, desirably lithium Li is added to this NO_x absorbent 19. When calling the ratio between the air and fuel (hydrocarbons) fed into the engine intake passage and the exhaust passage on the upstream side of the NO_x absorbent 19 the air-fuel ratio of the inflowing exhaust gas to the NO_x absorbent 19, this NO_x absorbent 19 performs the function of NO_x absorption and releasing of absorbing the NO_x when the air-fuel ratio of the inflowing exhaust gas is lean, while releasing the absorbed NO_x when the oxygen concentration in the inflowing exhaust gas is lowered. Note that, where the fuel (hydrocarbons) or air is not fed into the exhaust passage on the upstream side of the NO_x absorbent 19, the air-fuel ratio of the inflowing exhaust gas coincides with the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3, and accordingly, in this case, the NO_x absorbent 19 will absorb the NO_x when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is lean, while releases the absorbed NO_x when the oxygen concentration in the air-fuel mixture fed into the combustion chamber 3 is lowered.

[0017] When the above-mentioned NO_x absorbent 19 is arranged in the engine exhaust passage, this NO_x absorbent 19 actually performs the NO_x absorption and releasing action, but there are areas of uncertainty about the detailed mechanism of this absorption and releasing function. However, this absorption and releasing function is considered to be carried out by the mechanism as shown in Figs. 5A and 5B. Next, this mechanism will be explained taking as an example a case where platinum Pt and barium Ba are carried on the carrier, but the same mechanism is realized even if another precious metal, alkali metal, alkali earths, or rare earths is used.

[0018] Namely, when the inflowing exhaust gas becomes considerably lean, the oxygen concentration in the inflowing exhaust gas is greatly increased, and as shown in Fig. 5A, this oxygen O₂ is deposited on the surface of the platinum Pt in the form of O₂⁻ or O²⁻. On the other hand, the NO in the inflowing exhaust gas is reacted with O₂⁻ or O²⁻ on the surface of the platinum Pt and becomes NO₂ (2NO + O₂ → 2NO₂). Subsequently, a part of the produced NO₂ is oxidized on the platinum Pt, while absorbed into the absorbent, and bonded with the barium oxide BaO, while diffused in the form of the

nitric acid ion NO₃⁻ into the absorbent as shown in Fig. 5A. In this way, the NO_x is absorbed into the NO_x absorbent 19.

[0019] So far as the oxygen concentration in the inflowing exhaust gas is high, the NO₂ is produced on the surface of the platinum Pt, and so far as the NO_x absorption capability of the absorbent is not saturated, the NO₂ is absorbed into the absorbent and the nitric acid ion NO₃⁻ is produced. Contrary to this, when the oxygen concentration in the inflowing exhaust gas is lowered and the amount of production of NO₂ is lowered, the reaction is advanced in a reverse direction (NO₃⁻ → NO₂), thus the nitric acid ion NO₃⁻ in the absorbent is released in the form of NO₂ from the absorbent. Namely, this means that, when the oxygen concentration in the inflowing exhaust gas is lowered, the NO_x will be released from the NO_x absorbent 19. As shown in Fig. 4, when the degree of leanness of the inflowing exhaust gas becomes low, the oxygen concentration in the inflowing exhaust gas is lowered, and accordingly when the degree of leanness of the inflowing exhaust gas is lowered, even if the air-fuel ratio of the inflowing exhaust gas is lean, the NO_x will be released from the NO_x absorbent 19.

[0020] On the other hand, when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich and the air-fuel ratio of the inflowing exhaust gas becomes rich, as shown in Fig. 4, a large amount of unburnt HC and CO are discharged from the engine, and these unburnt HC and CO are reacted with the oxygen O₂⁻ or O²⁻ on the platinum Pt and oxidized. Also, when the air-fuel ratio of the inflowing exhaust gas becomes rich, the oxygen concentration in the inflowing exhaust gas is extremely lowered, and therefore the NO₂ is released from the absorbent, and this NO₂ is reacted with the unburnt HC and CO and reduced as shown in Fig. 5B. In this way, when the NO₂ no longer exists on the surface of the platinum Pt, the NO₂ is successively released from the absorbent. Accordingly, this means that, when the air-fuel ratio of the inflowing exhaust gas is made rich, NO_x is released from the NO_x absorbent 19 in a short time.

[0021] Namely, when the air-fuel ratio of the inflowing exhaust gas is made rich, first of all, the unburnt HC and CO are immediately reacted with the O₂⁻ or O²⁻ on the platinum Pt and oxidized, and subsequently if the unburnt HC and CO still remain even if the O₂⁻ or O²⁻ on the platinum Pt are consumed, the NO_x released from the absorbent and the NO_x discharged from the engine are reduced by these unburnt HC and CO. Accordingly, when the air-fuel ratio of the inflowing exhaust gas is made rich, the NO_x absorbed in the NO_x absorbent 19 is released in a short time, and in addition, this released NO_x is reduced, and therefore this means that it is possible to prevent the discharge of NO_x into the atmosphere. Also, the NO_x absorbent 19 has a function of a reduction catalyst, and therefore even if the air-fuel ratio of the inflowing exhaust gas is made the stoichiometric

air-fuel ratio, the NO_x released from the NO_x absorbent 19 is reduced. However, where the air-fuel ratio of the inflowing exhaust gas is made the stoichiometric air-fuel ratio, the NO_x can be only gradually released from the NO_x absorbent 19, and therefore a slightly long time is required for releasing all NO_x absorbed in the NO_x absorbent 19.

[0022] When the degree of leanness of the air-fuel ratio of the inflowing exhaust gas is made low as mentioned before, even if the air-fuel ratio of the inflowing exhaust gas is lean, the NO_x is released from the NO_x absorbent 19. Accordingly, so as to release the NO_x from the NO_x absorbent 19, it is sufficient if the oxygen concentration in the inflowing exhaust gas is lowered. Note, if the air-fuel ratio of the inflowing exhaust gas is lean even though the NO_x is released from the NO_x absorbent 19, the NO_x is not reduced in the NO_x absorbent 19, and accordingly in this case, it is necessary to provide a catalyst which can reduce the NO_x on the downstream side of the NO_x absorbent 19 or feed the reduction agent to the downstream side of the NO_x absorbent 19. Of course, it is possible to reduce the NO_x on the downstream side of the NO_x absorbent 19 in this way, but it is rather preferred that the NO_x be reduced in the NO_x absorbent 19. Accordingly, when the NO_x should be released from the NO_x absorbent 19, it is more preferable that the air-fuel ratio of the inflowing exhaust gas be made the stoichiometric air-fuel ratio or rich.

[0023] As shown in Fig. 3, in the embodiment according to the present invention, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich at the time of the warm-up operation and at the time of full load operation and the air-fuel ratio of the air-fuel mixture is made the stoichiometric air-fuel ratio at the time of the acceleration operation, but in most of the operating region other than these, a lean air-fuel mixture is burned in the combustion chamber 3. In this case, the air-fuel ratio of the air-fuel mixture burned in the combustion chamber 3 is almost 18.0 or more, and in the embodiment shown in Fig. 1, a lean air-fuel mixture having an air-fuel ratio of about 20 to 24 is burned. When the air-fuel ratio becomes 18.0 or more, even if the three-way catalyst has a reduction property under a lean air-fuel ratio, it cannot sufficiently reduce the NO_x , and accordingly the three-way catalyst cannot be used for reducing the NO_x under such a lean air-fuel ratio. Also, there is a Cu - zeolite catalyst as a catalyst which can reduce the NO_x even if the air-fuel ratio is 18.0 or more, but this Cu - zeolite catalyst lacks heat resistance, and therefore it is not actually preferred that this Cu - zeolite catalyst be used. Accordingly, in the end, there is no way except that the NO_x absorbent 19 which has been used in the present invention be used for removing the NO_x when the air-fuel ratio is 18.0 or more.

[0024] In the embodiment according to the present invention, as mentioned above, at the time of the full load operation, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, while at the time

of an acceleration operation, the air-fuel ratio of the air-fuel mixture is made the stoichiometric air-fuel ratio, and therefore this means that the NO_x is released from the NO_x absorbent 19 at the time of the full load operation and at the time of the acceleration operation. However, when the frequency of such a full load operation or acceleration operation being carried out is small, even if the NO_x is released from the NO_x absorbent 19 only at the time of the full load operation and the time of the acceleration operation, the absorption capability of NO_x by the NO_x absorbent 19 is saturated during a period when the lean air-fuel mixture is burned, and thus the NO_x can no longer be absorbed by the NO_x absorbent 19. Accordingly, when the lean air-fuel mixture is being continuously burned, it is necessary to periodically make the air-fuel ratio of the inflowing exhaust gas rich or periodically make the air-fuel ratio of the inflowing exhaust gas the stoichiometric air-fuel ratio and periodically release the NO_x from the NO_x absorbent 19.

[0025] SO_x is contained in the exhaust gas, and not only NO_x , but also SO_x are absorbed into the NO_x absorbent 19. It can be considered that the mechanism of the absorption of SO_x into the NO_x absorbent 19 is the same as the absorption mechanism of the NO_x .

[0026] Namely, when explaining this by taking as an example a case where platinum Pt and barium Ba are carried on the carrier in the same way as in the explanation of the absorption mechanism of NO_x , as mentioned before, when the air-fuel ratio of the inflowing exhaust gas is lean, the oxygen O_2 is deposited on the surface of the platinum Pt in the form of O_2^- or O^{2-} , and the SO_x in the inflowing exhaust gas reacts with the O_2^- or O^{2-} on the surface of the platinum Pt and becomes SO_3 . Subsequently, a part of the produced SO_3 is further oxidized on the platinum Pt, while absorbed into the absorbent, and bonded with the barium oxide BaO , while diffused in the absorbent in the form of the sulfuric acid ion SO_4^{2-} to produce a stable sulfate BaSO_4 .

[0027] However, this sulfate BaSO_4 is stable and difficult to decompose, and even if the air-fuel ratio of the inflowing exhaust gas is made rich, the sulfate BaSO_4 remains as it is without decomposition. Accordingly, as the time is elapsed, the sulfate BaSO_4 is increased in the NO_x absorbent 19, and thus as time elapses, the amount of NO_x that can be absorbed by the NO_x absorbent 19 will be lowered.

[0028] Therefore, in the embodiment according to the present invention, so as to prevent the SO_x from flowing into the NO_x absorbent 19, an SO_x absorbent 18 which absorbs the SO_x when the air-fuel ratio of the inflowing exhaust gas is lean, while releases the absorbed SO_x when the air-fuel ratio of the inflowing exhaust gas becomes rich and, at the same time, has a function of the three-way catalyst, is arranged on the upstream side of the NO_x absorbent 19. This SO_x absorbent 18 absorbs also NO_x together with SO_x when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 is lean, but releases not only the absorbed NO_x , but also the

absorbed SO_x when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 is made rich.

[0029] As mentioned above, in the NO_x absorbent 19, when the SO_x is absorbed, a stable sulfate BaSO_4 is formed, and as a result, even if the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent 19 is made rich, the SO_x no longer will be released from the NO_x absorbent 19. Accordingly, so as to release the SO_x from the SO_x absorbent 18 when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 is made rich, it becomes necessary to make the absorbed SO_x exist in the absorbent in the form of the sulfuric acid ion SO_4^{2-} , or to make the sulfate BaSO_4 exist in the absorbent in an unstable state even if the sulfate BaSO_4 is produced. As the SO_x absorbent 18 enabling this, use can be made of an absorbent which carries at least one member selected from a transition metal such as copper Cu, iron Fe, manganese Mn, and nickel Ni, sodium Na, tin Sn, titanium Ti, and lithium Li on a carrier made of alumina. In this case, it is clarified that the absorbent carrying the lithium Li on the carrier made of alumina is the most preferred.

[0030] In this SO_x absorbent 18, when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 is lean, the SO_x contained in the exhaust gas is oxidized on the surface of the absorbent and absorbed into the absorbent in the form of the sulfuric acid ion SO_4^{2-} and then diffused in the absorbent. In this case, when the platinum Pt is caught on the carrier of the SO_x absorbent 18, SO_x becomes easily adhered onto the platinum Pt in the form of SO_3^{2-} , and thus the SO_2 becomes easily absorbed into the absorbent in the form of the sulfuric acid ion SO_4^{2-} . Accordingly, so as to promote the absorption of the SO_2 , preferably the platinum Pt is carried on the carrier of the SO_x absorbent 18. As mentioned above, when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 becomes lean, the SO_x is absorbed into the SO_x absorbent 18, and accordingly only the NO_x is absorbed into the NO_x absorbent 19 provided on the downstream side of the SO_x absorbent 18.

[0031] On the other hand, as mentioned before, the SO_x absorbed in the SO_x absorbent 18 has been diffused in the absorbent in the form of the sulfuric acid ion SO_4^{2-} , or has become the sulfate BaSO_4 in an unstable state. Accordingly, when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 becomes rich, the SO_x absorbed in the SO_x absorbent 18 will be released from the SO_x absorbent 18. At this time, the NO_x is simultaneously released from the NO_x absorbent 19.

[0032] As mentioned before, when the NO_2 on the surface of the platinum Pt no longer exists, in the NO_x absorbent 19, the reaction is immediately advanced in the direction of $(\text{NO}_3^- \rightarrow \text{NO}_2)$, and the NO_x is immediately released from the absorbent. When the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent 19 is made rich, the NO_2 on the surface of platinum Pt is immediately reduced by the unburnt HC and CO, and therefore the NO_2 on the surface of the platinum Pt im-

mediately disappears, and thus, as shown in Fig. 6, the NO_x will be released from the NO_x absorbent in a short time. Namely, this means that the NO_x releasing speed of the NO_x absorbent 19 is considerably high.

[0033] Contrary to this, the SO_x absorbed in the SO_x absorbent 18 is difficult to decompose since it is more stable than the NO_x absorbed in the NO_x absorbent 19. The decomposition of this SO_x is not caused unless the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 is made rich. Namely, when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 is made rich, the SO_x in the SO_x absorbent 18 is decomposed and released from the absorbent. This decomposition speed is considerably slow, and thus, as shown in Fig. 6, even if the air-fuel ratio of the inflowing exhaust gas to the SO_x absorbent 18 is made rich, a long time is required until the releasing of the SO_x is completed in comparison with NO_x . Namely, this means that the releasing speed of the SO_x is considerably slow in comparison with the releasing speed of the NO_x .

[0034] As mentioned before, when the NO_x should be released from the NO_x absorbent 19, preferably the air-fuel ratio of the inflowing exhaust gas is made the stoichiometric air-fuel ratio or rich. However, if the air-fuel ratio of the inflowing exhaust gas is not made rich, the SO_x is not released from the SO_x absorbent 18. Accordingly, in the embodiment according to the present invention, when the SO_x should be released from the SO_x absorbent 18 and the NO_x should be released from the NO_x absorbent 19, the air-fuel ratio of the inflowing exhaust gas is made rich.

[0035] When the air-fuel ratio of the inflowing exhaust gas is made rich, the SO_x is released from the SO_x absorbent 18, and the NO_x is released from the NO_x absorbent 19. However, if the SO_x released from the SO_x absorbent 18 flows into the NO_x absorbent 19 when the NO_2 is being released from the NO_x absorbent 19, the SO_2 and the NO_2 are reacted in the NO_x absorbent 19 ($\text{SO}_2 + \text{NO}_2 \rightarrow \text{SO}_3 + \text{NO}$), and thus the produced SO_3 is absorbed into the NO_x absorbent 19 in the form of SO_4^{2-} . However, as mentioned before, the releasing speed of the NO_x is considerably slower than the releasing speed of the SO_x as shown in Fig. 6, and accordingly the most part of the SO_2 released from the SO_x absorbent 18 flows into the NO_x absorbent 19 after the NO_x releasing action from the NO_x absorbent 19 is completed. Accordingly, the amount of SO_x absorbed into the NO_x absorbent 19 becomes small.

[0036] On the other hand, in the embodiment shown in Fig. 1, the releasing action of the SO_x from the SO_x absorbent 18 and the releasing action of the NO_x from the NO_x absorbent 19 are carried out when the predetermined amount of NO_x is absorbed into the NO_x absorbent 19, for example, the NO_x absorbent 19 absorbs the NO_x in an amount of 50 percent based on the total absorption capability of the same. The amount of the NO_x absorbed into the NO_x absorbent 19 is in proportion to the amount of the exhaust gas discharged from en-

gine and the NO_x concentration in the exhaust gas. In this case, the exhaust gas amount is in proportion to the intake air amount, and the concentration of NO_x in the exhaust gas is in proportion to the engine load, and therefore the amount of NO_x absorbed into the NO_x absorbent 19 becomes correctly in proportion to the intake air amount and engine load. Accordingly, the amount of the NO_x absorbed in the NO_x absorbent 19 can be estimated from the cumulative value of the product of the intake air amount and the engine load, but in the embodiment shown in Fig. 1, it is simplified and the amount of NO_x absorbed in the NO_x absorbent 19 is estimated from the cumulative value of the engine rotational speed.

[0037] Next, an explanation will be made of one embodiment of the absorption and releasing control of the NO_x absorbent 19 referring to Fig. 7 and Fig. 8.

[0038] Figure 7 shows an interruption routine executed at every predetermined time interval.

[0039] Referring to Fig. 7, first of all, at step 100, it is determined whether or not the correction coefficient K with respect to the basic fuel injection time TP is smaller than 1.0, that is, whether or not a lean air-fuel mixture is being burned. When $K < 1.0$, that is, when a lean air-fuel mixture is being burned, the processing routine goes to step 101, at which the result of addition of ΣNE to the current engine rotational speed NE is made ΣNE . Accordingly, this ΣNE indicates the cumulative value of the engine rotational speed NE. Subsequently, at step 102, it is determined whether or not the cumulative rotational speed ΣNE is larger than the constant value SNE. This constant value SNE indicates the cumulative rotational speed from which it is estimated that the NO_x in an amount of for example 50 percent based on the total NO_x absorption capability of the NO_x absorbent 19 has been absorbed in the NO_x absorbent 19. When $\Sigma NE \leq SNE$, the processing cycle is completed, while when $\Sigma NE > SNE$, that is, when it is estimated that the NO_x in an amount of 50 percent based on the total NO_x absorption capability of the NO_x absorbent 19 has been absorbed in the NO_x absorbent 19, the processing routine goes to step 103, at which the NO_x releasing flag is set. When the NO_x releasing flag is set, as will be mentioned later, the air-fuel ratio of the air-fuel mixture to be fed into the engine cylinder is made rich.

[0040] Subsequently, at step 104, the count value C is incremented exactly by one. Subsequently, at step 105, it is determined whether or not the count value C becomes larger than the constant value C_0 , that is whether or not for example 5 seconds have elapsed. When $C \leq C_0$, the processing routine is completed, and when C becomes smaller than C_0 , the processing routine goes to step 106, at which the NO_x releasing flag is reset. When the NO_x releasing flag is reset, as will be mentioned later, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is switched from rich to lean, and thus the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made rich for 5 seconds. Subse-

quently, at step 107, the cumulative rotational speed ΣNE and the count value C are made zero.

[0041] On the other hand, at step 100, when it is decided that $K \geq 1.0$, that is, when the air-fuel ratio of the air-fuel mixture being fed into the engine cylinder is the stoichiometric air-fuel ratio or rich, the processing routine goes to step 108, at which it is determined whether or not the state of $K \geq 1.0$ is continued for the predetermined time, for example, 10 seconds. When the state of $K \geq 1.0$ is not continued for the predetermined time, the processing cycle is completed, and when the state of $K \geq 1.0$ is continued for the constant time, the processing routine goes to step 109, at which the cumulative rotational speed ΣNE is made zero.

[0042] Namely, when the time during which the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made the stoichiometric air-fuel ratio or rich continues for about 10 seconds, it is considered that the most part of the SO_x absorbed in the SO_x absorbent 18 was released and, at the same time, the most part of the NO_x absorbed in the NO_x absorbent 19 was released, and accordingly, in this case, the cumulative rotational speed ΣNE is made zero at step 109.

[0043] Figure 8 shows a calculation routine of the basic fuel injection time TAU, which routine is repeatedly executed.

[0044] Referring to Fig. 8, first, at step 200, the basic fuel injection time TP is calculated from the map shown in Fig. 2. Subsequently, at step 201, it is determined whether or not the operation state is that where the combustion of a lean air-fuel mixture should be carried out. When it is not the operation state where the combustion of a lean air-fuel mixture should be carried out, that is, at the time of the warm-up operation or the time of the acceleration operation or the time of the full load operation, the processing routine goes to step 202, at which the correction coefficient K is calculated. At the time of the engine warm-up operation, this correction coefficient K is a function of the engine coolant temperature and becomes smaller within the range where $K \geq 1.0$ as the engine coolant temperature becomes higher. Also, at the time of the acceleration operation, the correction coefficient K is made 1.0, and at the time of the full load operation, the correction coefficient K is made a value larger than 1.0. Subsequently, at step 203, the correction coefficient K is made K_t , and then at step 204, the fuel injection time TAU ($= TP \cdot K_t$) is calculated. At this time, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made the stoichiometric air-fuel ratio or rich.

[0045] On the other hand, when it is determined at step 201 that it is the operation state where the combustion of a lean air-fuel mixture should be carried out, the processing routine goes to step 205, at which it is determined whether or not the NO_x releasing flag has been set. When the NO_x releasing flag has not been set, the processing routine goes to step 206, at which the correction coefficient K is made for example 0.6, and then

at step 207, after the correction coefficient K is made K_t , the processing routine goes to step 204. Accordingly, at this time, the lean air-fuel mixture is fed into the engine cylinder. On the other hand, when it is decided at step 205 that the NO_x releasing flag is set, the processing routine goes to step 208, at which the predetermined value KK is made K_t , and then the processing routine goes to step 204. This value KK is a value of about 1.1 to 1.2 with which the air-fuel ratio of the air-fuel mixture fed into the engine cylinder becomes about 12.0 to 13.5. Accordingly, at this time, the rich air-fuel mixture is fed into the engine cylinder, whereby the SO_x absorbed in the SO_x absorbent 18 will be released and, at the same time, the NO_x absorbed in the NO_x absorbent 19 will be released.

[0046] Figure 9 shows another embodiment. In this embodiment, the same constituent elements as those shown in Fig. 1 are indicated by the same symbols.

[0047] As shown in Fig. 9, in this embodiment, an exhaust manifold 16 is connected to the inlet portion of a casing 41 containing an SO_x absorbent 40, and the outlet portion of the casing 40 is connected via the exhaust pipe 42 to the inlet portion of a casing 44 containing an NO_x absorbent 43. Also in this embodiment, when the lean air-fuel mixture is being burned in the combustion chamber 3, the SO_x is absorbed into the SO_x absorbent 40 and, at the same time, the NO_x is absorbed into the NO_x absorbent 43. On the other hand, when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, the SO_x is released from the SO_x absorbent 40, and the NO_x is released from the NO_x absorbent 43.

[0048] Figure 10 shows a case where the present invention is applied to a diesel engine. Note that, in Fig. 10, constituent elements the same as those shown in Fig. 1 are indicated by the same symbols.

[0049] In the diesel engine, usually in all operation states, combustion is performed in a state where an air excess rate is 1.0 or more, that is, the average air-fuel ratio of the air-fuel mixture in the combustion chamber 3 is lean. Accordingly, the SO_x discharged at this time is absorbed into the SO_x absorbent 18, and the NO_x discharged at this time is absorbed into the NO_x absorbent 19. On the other hand, when the SO_x should be released from the SO_x absorbent 18 and, at the same time, the NO_x should be released from the NO_x absorbent 19, the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 and the NO_x absorbent 19 is made rich. In this case, in the embodiment shown in Fig. 10, the average air-fuel ratio of the air-fuel mixture in the combustion chamber 3 is made lean and the hydrogen carbide is fed into the engine exhaust passage on the upstream side of the SO_x absorbent 18, whereby the air-fuel ratio of the inflowing exhaust gas to the SO_x absorbent 18 and the NO_x absorbent 19 is made rich.

[0050] Referring to Fig. 10, in this embodiment, a load sensor 51 generating an output voltage in proportion to an amount of depression of an accelerator pedal 50 is

provided, and the output voltage of this load sensor 51 is input via the AD converter 52 to the input port 35. Also, in this embodiment, a reduction agent feeding valve 60 is arranged in an exhaust pipe 17, which reduction agent feeding valve 60 is connected via a feeding pump 61 to a reduction agent tank 62. The output port 36 of the electronic control unit 30 is connected via drive circuits 38 to the reduction agent feeding valve 60 and the feeding pump 61, respectively. In the reduction agent tank 62, a hydrocarbon such as gasoline, isoctane, hexane, heptane, light oil or a lamp oil, or a hydrocarbon which can be stored in a liquid state, for example, butane or propane is filled.

[0051] In this embodiment, the air-fuel mixture in the combustion chamber 3 is usually burned under an excess of air, that is, in a state where the average air-fuel ratio is lean. At this time, the SO_x discharged from the engine is absorbed into the SO_x absorbent 18 and, at the same time, the NO_x discharged from the engine is absorbed into the NO_x absorbent 19. When the SO_x should be released from the SO_x absorbent 18 and, at the same time the NO_x should be released from the NO_x absorbent 19, the feeding pump 61 is driven and, at the same time, the reduction agent feeding valve 60 is opened, whereby the hydrocarbon filled in the reduction agent tank 62 is fed from the reduction agent feeding valve 60 to the exhaust pipe 17 for a constant time, for example, about 5 seconds to 20 seconds. The amount of feeding of the hydrocarbon at this time is determined so that the air-fuel ratio of the inflowing exhaust gas flowing into the SO_x absorbent 18 and the NO_x absorbent 19 becomes rich, and accordingly, at this time, the SO_x will be released from the SO_x absorbent 18, and the NO_x will be released from the NO_x absorbent 19.

[0052] Figure 11 shows a routine for executing this NO_x releasing processing, which routine is executed by interruption at every predetermined time interval.

[0053] Referring to Fig. 11, first of all, at step 300, the result of addition of ΣNE to the current engine rotational speed NE is made ΣNE . Accordingly, this ΣNE indicates the cumulative value of the engine rotational speed NE . Subsequently, at step 301, it is determined whether or not the cumulative rotational speed ΣNE is larger than the constant value SNE . This constant value SNE indicates the cumulative rotational speed from which it is estimated that the NO_x in an amount of for example 50 percent based on the total NO_x absorption capability of the NO_x absorbent 19 has been absorbed in the NO_x absorbent 19. When $\Sigma NE \leq SNE$, the processing cycle is completed, while when $\Sigma NE > SNE$, that is, when it is estimated that the NO_x in an amount of 50 percent based on the total NO_x absorption capability of the NO_x absorbent 19 has been absorbed in the NO_x absorbent 19, the processing routine goes to step 302, at which the feeding pump 61 is driven for a constant time, for example, for about 5 seconds to 20 seconds. Subsequently, at step 303, the reduction agent feeding valve 60 is opened for a constant time, for example, for about

5 seconds to 20 seconds, and then, at step 304, the cumulative rotational speed ΣNE is made zero.

[0054] Figure 12 shows a further embodiment. Note that, in Fig. 12, constituent elements the same as those shown in Fig. 1 are indicated by the same symbols.

[0055] Referring to Fig. 12, in this embodiment, a temperature sensor 22 is arranged in the exhaust pipe 17 on the upstream side of the casing 20. This temperature sensor 22 generates an output voltage in proportion to the exhaust gas temperature flowing in the exhaust pipe 17, and this output voltage is input to the input port 35 via the AD converter 37. Further, in this embodiment, a bidirectional bus 31 is connected to a backup RAM 33a always connected to the power source.

[0056] This embodiment prevents the SO_x released from the SO_x absorbent 18 from being absorbed into the NO_x absorbent 19 as much as possible. Note that, in this embodiment, the releasing control of the SO_x and NO_x is carried out considering also the temperature of the SO_x absorbent 18. Accordingly, first of all, an explanation will be made of a relationship between the temperature of the SO_x absorbent 18 and the releasing function of the SO_x .

[0057] Namely, the decomposition function of the SO_x absorbed in the SO_x absorbent 18 depends on the temperature of the SO_x absorbent 18, and the decomposition becomes more difficult as the temperature of the SO_x absorbent 18 becomes lower. Accordingly, as the temperature of the SO_x absorbent 18 becomes lower, the SO_x becomes harder to be decomposed unless the air-fuel ratio of the air-fuel mixture flowing into the SO_x absorbent 18 is made rich, and thus this means that the SO_x is not released from the SO_x absorbent 18. Figure 13 shows a relationship between the air-fuel ratio A/F of the inflowing exhaust gas with which the SO_x absorbent 18 can release the SO_x and the temperature T of the SO_x absorbent 18. It is seen from Fig. 13 that, so as to release the SO_x , the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 must be made richer as the temperature T of the SO_x absorbent 18 becomes lower.

[0058] Also in this embodiment, when the NO_x and SO_x should be released, the air-fuel mixture fed into the combustion chamber 3 is periodically made rich, and Fig. 14 shows a timing at which the air-fuel ratio of the air-fuel mixture is made rich in this way. Note that, in Fig. 14, P indicates a timing at which the NO_x is released from the NO_x absorbent 19, and Q indicates a timing at which the SO_x is released from the SO_x absorbent 18. As seen from Fig. 14, so as to release the NO_x from the NO_x absorbent 19, the period for which the air-fuel ratio of the air-fuel mixture is made rich is considerably short, and the air-fuel ratio of air-fuel mixture is made rich with a proportion of one time per several minutes. On the other hand, the amount of SO_x contained in the exhaust gas is considerably smaller in comparison with the amount of NO_x , and therefore a considerably long time is taken until the SO_x absorbent 18 is saturated by the

SO_x . Accordingly, the period for which the air-fuel ratio of air-fuel mixture is made rich so as to release the SO_x from the SO_x absorbent 18 is considerably long, for example, the air-fuel ratio of air-fuel mixture is made rich

5 with a proportion of one time per several hours.

[0059] As shown in Fig. 6, when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, the NO_x is released from the NO_x absorbent 19 in a short time, but a considerably long time is required until the SO_x is released from the SO_x absorbent 18. Accordingly, in this embodiment, a time for which the air-fuel ratio of air-fuel mixture is continuously made rich so as to release the SO_x is made considerably longer than the time for which the air-fuel ratio of air-fuel mixture is continuously made rich so as to release the NO_x . For example, in contrast to a fact that the air-fuel ratio of air-fuel mixture is made rich for about several seconds when the NO_x is to be released, the air-fuel ratio of air-fuel mixture is made rich for about several minutes when the SO_x is to be released. In this way, the air-fuel ratio of air-fuel mixture is made rich over a long time when the SO_x is released, but as mentioned above, a period for which the air-fuel ratio of air-fuel mixture is made rich for the release of the SO_x is long, and therefore a great increase of the fuel consumption amount will not be caused by this.

[0060] Figure 15 shows a rich control of the air-fuel mixture when releasing the NO_x (P of Fig. 14). Note that, K_t indicates the correction coefficient with respect to the basic fuel injection time T_P .

[0061] As shown in Fig. 15, when the NO_x should be released from the NO_x absorbent 19, the air-fuel ratio of the air-fuel mixture air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich by increasing the correction coefficient K_t up to $KK (> 1.0)$, and then maintained at this rich state only for the time C_1 . Subsequently, the correction coefficient K_t is gradually reduced, and then the correction coefficient K_t is maintained at 1.0, that is, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is maintained at the stoichiometric air-fuel ratio. Subsequently, when the time C_2 has elapsed when the rich control is started, the correction coefficient K_t is made smaller than 1.0 again, and the combustion of the lean air-fuel mixture is started again.

[0062] When the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes rich ($K_t = KK$), the most part of the NO_x absorbed in the NO_x absorbent 19 is abruptly released. The value of the correction coefficient KK and the time C_1 are determined so as to generate the unburnt HC and CO in an amount necessary for consuming the O_2^- or O_2^+ on the surface of the platinum Pt and reducing the whole NO_x at this time. In this case, as the exhaust gas temperature becomes higher and the temperature of the NO_x absorbent 19 becomes higher, the amount of the NO_x released from the NO_x absorbent 19 is increased. Accordingly, as shown in Fig. 16A, the value of the correction coeffi-

cient KK is made larger as the exhaust gas temperature T becomes higher, and as shown in Fig. 16B, the time C₁ is made shorter as the exhaust gas temperature T becomes higher. Note that, a relationship between the correction coefficient KK and the exhaust gas temperature T shown in Fig. 16A and the relationship between the time C₁ and the exhaust gas temperature T shown in Fig. 16B are stored in advance in the ROM 32.

[0063] On the other hand, as mentioned before, when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes rich (Kt = KK), the most part of the NO_x absorbed in the NO_x absorbent 19 is abruptly released, and thereafter even if the air-fuel ratio has been made rich, the NO_x is released from the NO_x absorbent 19 only little by little. Accordingly, when the air-fuel ratio is continuously made rich, the unburnt HC and CO will be released into the atmosphere. Therefore, in this embodiment, as shown in Fig. 15, after the air-fuel ratio is made rich (Kt = KK), the degree of richness is made gradually smaller, and subsequently the air-fuel ratio is maintained at the stoichiometric air-fuel ratio (Kt = 1.0), and the NO_x gradually released from the NO_x absorbent 18 is sequentially reduced.

[0064] Note that, as the amount of the NO_x released from the NO_x absorbent 19 is larger when the air-fuel ratio is made rich, the amount of the NO_x released from the NO_x absorbent 19 becomes smaller, and accordingly a time until the NO_x absorbent 19 ends releasing NO_x becomes short. As mentioned before, as the exhaust gas temperature T becomes higher, the amount of the NO_x released from the NO_x absorbent 19 becomes larger when the air-fuel ratio is made rich, and accordingly, as shown in Fig. 16C, a time C₂ of from when the air-fuel ratio is made rich to when it is returned to lean again is made shorter as the exhaust gas temperature T becomes higher. Note that, a relationship between the time C₂ and the exhaust gas temperature T shown in Fig. 16C is stored in advance in the ROM 32.

[0065] In this way, KK, C₁, and C₂ are controlled in accordance with the exhaust gas temperature T, and when the exhaust gas temperature T is high, the correction coefficient Kt is changed with a pattern indicated by a solid line of Fig. 15, and changed with a pattern indicated by a broken line of Fig. 15 when the exhaust gas temperature T is low. Note that, in this case, a time for which the air-fuel ratio of air-fuel mixture is rich is short, and therefore almost no SO_x is released from the SO_x absorbent 18, and substantially only the NO_x releasing action from the NO_x absorbent 19 is carried out.

[0066] Figure 17 shows the rich control of the air-fuel mixture when the SO_x is released (Q in Fig. 14).

[0067] As shown in Fig. 17, even when the SO_x should be released from the SO_x absorbent 18, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich by increasing the correction coefficient Kt up to KK (>1.0), and then maintained at this rich state only for the time C₁. Subsequently, the correction coefficient Kt is gradually reduced, and then the correction

coefficient Kt is maintained at Ko (> 1.0), that is the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is continuously maintained rich. Namely, when the SO_x should be released, first of all, the air-fuel

ratio of air-fuel mixture is made very rich up to the first degree of richness (Kt = KK), and thereafter maintained at a second degree of richness (Kt = Ko) smaller than this first degree of richness (Kt = KK). Subsequently, when the time C₂ has elapsed when the rich control is started, the correction coefficient Kt is made smaller than 1.0 again, and the combustion of the lean air-fuel mixture is started again. Note that, the time C₂ when the SO_x is released is considerably longer in comparison with the time C₁ at the time of releasing of the NO_x shown in Fig. 15 and for example is about 3 minutes to 10 minutes.

[0068] As mentioned before, the SO_x releasing speed from the SO_x absorbent 18 is considerably slow, and accordingly even if the air-fuel ratio of the air-fuel mixture

is continuously made rich, the releasing of the SO_x cannot be completed in a short time. Namely, making the air-fuel ratio of the air-fuel mixture very rich leads to only an increase of the fuel consumption amount. Accordingly, when the SO_x should be released, the air-fuel ratio of the air-fuel mixture is maintained at the lowest degree of richness with which the NO_x can be released well, and this lowest degree of richness is indicated by Ko in Fig. 17. Accordingly, if the correction coefficient Kt is maintained at Ko, the SO_x will be released well from the SO_x absorbent 18. When the SO_x should be released irrespective of this, first of all, the air-fuel ratio of air-fuel mixture is made very rich (Kt = KK). The reason for this will be explained next.

[0069] If the correction coefficient Kt is maintained at Ko when the SO_x should be released, the SO_x is gradually released from the SO_x absorbent 18. At this time, the NO_x is simultaneously released from the NO_x absorbent 19, but the degree of richness is small, and therefore the NO_x is gradually released also from the NO_x absorbent 19. However, if the SO_x released from the SO_x absorbent 18 is flowing into the NO_x absorbent 19 when the NO_x is gradually released from the NO_x absorbent 19 in this way, as mentioned before, the NO₂ and SO₂ react with each other (SO₂ + NO₂ → SO₃ + NO), and thus the produced SO₃ will be absorbed into the NO_x absorbent 19 in the form of SO₄⁻. Such a reaction is not caused so far as the NO₂ does not exist, and accordingly so as to prevent the SO₂ from absorption into the NO_x absorbent 19, it is necessary to prevent the

NO₂ from releasing from the NO_x absorbent 19 when the SO_x is being released from the SO_x absorbent 18. For this purpose, as shown in Fig. 17, when the SO_x should be released, first of all the air-fuel ratio of the air-fuel mixture is made very rich (Kt = KK).

[0070] Namely, when the air-fuel ratio of the air-fuel mixture is made very rich (Kt = KK), the most part of the NO₂ is released from the NO_x absorbent 19 at one time, and thereafter almost no NO₂ is released from the NO_x

absorbent 19. Accordingly, thereafter the SO_2 released from the SO_x absorbent 18 will not react with the NO_2 when the correction coefficient K_t is maintained at K_0 , and thus a risk of absorption of the SO_2 into the NO_x absorbent 19 is eliminated.

[0071] As mentioned before, when the air-fuel ratio of the air-fuel mixture becomes rich ($K_t = K_K$), the most part of the NO_x absorbed in the NO_x absorbent 19 is abruptly released, and at this time, as the exhaust gas temperature is higher, and accordingly the temperature of the NO_x absorbent 19 is higher, the amount of the NO_x released from the NO_x absorbent 19 is increased. Accordingly, as shown in Fig. 18A, the value of the correction coefficient K_K is made larger as the exhaust gas temperature T becomes higher, and as shown in Fig. 18B, the time C_1 is made shorter as the exhaust gas temperature T becomes higher. Note that, a relationship between the correction coefficient K_K and the exhaust gas temperature T shown in Fig. 18A and the relationship between the time C_1 and the exhaust gas temperature T shown in Fig. 18B are stored in advance in the ROM 32.

[0072] On the other hand, after the air-fuel ratio of the air-fuel mixture is made very rich ($K_t = K_K$), it is maintained at a relatively small degree of richness ($K_t = K_0$), and at this time, the SO_x is continuously released from the SO_x absorbent 18. At this time, as shown in Fig. 13, as the temperature of the SO_x absorbent 18, that is the exhaust gas temperature T becomes higher, the SO_x can be continuously released even if the air-fuel ratio A/F of the air-fuel mixture is lowered. Accordingly, in this embodiment, as the exhaust gas temperature T becomes higher, the air-fuel ratio A/F of the air-fuel mixture is made smaller. Namely, when the exhaust gas temperature T is high, as indicated by a solid line in Fig. 17, the value of K_0 is made relatively small, and when the exhaust gas temperature T is low, as indicated by a broken line in Fig. 17, the value of K_0 is made relatively large. Figure 18C shows a relationship between this value of K_0 and the exhaust gas temperature T , which relationship is stored in advance in the ROM 32.

[0073] Note that, as the amount of the SO_x released from the SO_x absorbent 18 is larger when the air-fuel ratio of the air-fuel mixture is maintained rich ($K_t = K_0$), a time until the SO_x absorbent 18 terminates the release of SO_x becomes shorter. As mentioned before, as the exhaust gas temperature T becomes higher, the decomposition speed of SO_x becomes faster, and the releasing speed of SO_x becomes faster, and accordingly, as shown in Fig. 18D, a time C_2 from when the air-fuel ratio is made rich to when it is returned to lean again is made shorter as the exhaust gas temperature T becomes higher. Note that, a relationship between the time C_2 and the exhaust gas temperature T shown in Fig. 18D is stored in advance in the ROM 32.

[0074] As shown in Figs. 16A to 16C and Figs. 18A to 18D, the various values K_K , C_1 , K_0 , and C_2 are functions of the exhaust gas temperature T , and in this embodi-

ment, this exhaust gas temperature T is detected by the temperature sensor 22. In this way, it is also possible to directly detect the exhaust gas temperature T , but it is also possible to estimate the same from the intake air amount Q and the engine rotational speed N . In this case, it is sufficient if the relationship among the exhaust gas temperature T , the intake air amount Q , and the engine rotational speed N is found in advance from experiments and this relationship is stored in advance in the

ROM 32 in the form of a map as shown in Fig. 19 and the exhaust gas temperature T is calculated from this map.

[0075] Next, the absorption and releasing control of the NO_x and SO_x will be explained referring to Fig. 20 to Fig. 22.

[0076] Figure 20 and Fig. 21 show a calculation routine of the correction coefficient K_K at the time of rich control, which routine is executed by interruption at every predetermined time interval.

[0077] Referring to Fig. 20 and Fig. 21, first of all, it is determined at step 400 whether or not the correction coefficient K is smaller than 1.0, that is, whether or not the lean air-fuel mixture is being burned. When $K < 1.0$, that is, when the lean air-fuel mixture is being burned, the processing routine goes to step 401, at which the amount W_n of NO_x absorbed in the absorbent 19 is calculated. Namely, the amount of NO_x discharged from the combustion chamber 3 is increased as the intake air amount Q becomes larger, and increased as the engine load Q/N becomes higher, and therefore the amount W_n of the NO_x absorbed in the NO_x absorbent 19 will be represented by the sum of W_n and $K_1 \cdot Q \cdot Q/N$ (K_1 is a constant).

[0078] Subsequently, at step 402, the amount W_s of the SO_x absorbed in the SO_x absorbent 18 is calculated. Namely, the amount of SO_x discharged from the combustion chamber 3 is increased as the intake air amount Q becomes larger, and therefore the amount W_s of the SO_x absorbed in the SO_x absorbent 18 will be represented by the sum of W_s and $K_2 \cdot Q$ (K_2 is a constant). This SO_x amount W_s is stored in the backup RAM 33a. Subsequently, at step 403, it is determined whether or not the SO_x releasing flag indicating that the SO_x should be released has been set. When the SO_x releasing flag has not been set, the processing routine goes to step 404, at which it is determined whether or not the NO_x releasing flag indicating that the NO_x should be released has been set. When the NO_x releasing flag has not been set, the processing routine goes to step 405.

[0079] At step 405, it is determined whether or not the amount W of the SO_x absorbed in the SO_x absorbent 18 is larger than the predetermined set up amount W_{so} . This set up amount W_{so} is for example about 30 percent based on the maximum amount of SO_x that can be absorbed by the SO_x absorbent 18. When $W_s \leq W_{so}$, the processing routine goes to step 411. At step 411, it is determined whether or not the amount W_n of the NO_x absorbed in the NO_x absorbent 19 is larger than the pre-

determined set amount W_{so} . This set amount W_{so} is for example about 30 percent based on the maximum amount of NO_x that can be absorbed by the NO_x absorbent 19. When $W_n \leq W_{so}$, the processing cycle is completed.

[0080] On the other hand, when it is determined at step 405 that $W_s > W_{so}$, the processing routine goes to step 406, at which the SO_x releasing flag is set. Subsequently, at step 407, the correction coefficient KK is calculated from the relationship shown in Fig. 18A, and then at step 408, the time C_1 is calculated from the relationship shown in Fig. 18B. Subsequently, at step 409, the correction coefficient KK is calculated from the relationship shown in Fig. 18C, and then at step 410, the time C_2 is calculated from the relationship shown in Fig. 18D. Subsequently, the processing cycle is completed. Note that, when the SO_x releasing flag is set and various values KK , C_1 , Ko , and C_2 are calculated, as will be mentioned later, the air-fuel ratio of air-fuel mixture is made rich.

[0081] On the other hand, when it is determined that $W_n > W_{so}$ at step 411, the processing routine goes to step 412, at which the NO_x releasing flag is set. Subsequently, at step 413, the correction coefficient KK is calculated from the relationship shown in Fig. 16A, and then at step 414, the time C_1 is calculated from the relationship shown in Fig. 16B. Subsequently, at step 415, the correction coefficient Ko is made 1.0, and then at step 416, the time C_2 is calculated from the relationship shown in Fig. 16C. Subsequently, the processing cycle is completed. Note that, when the NO_x releasing flag is set and various values KK , C_1 , Ko , and C_2 are calculated, as will be mentioned later, the air-fuel ratio of air-fuel mixture is made rich.

[0082] When the SO_x releasing flag or the NO_x releasing flag is set, the processing routine goes from step 403 or step 404 to step 417, at which the count value C is incremented exactly by one. Subsequently, at step 418, it is determined whether or not the count value C is smaller than the time C_1 . When $C < C_1$, the processing cycle is completed, and accordingly the correction coefficient is maintained at KK as it is for the time C_1 . Subsequently, when C becomes equal to or larger than C_1 , the processing routine goes to step 419, at which it is determined whether or not the count value C is smaller than the time C_2 . When $C < C_2$, the processing routine goes to step 420, at which the predetermined value α is subtracted from the correction coefficient KK . Accordingly, the value of the correction coefficient KK becomes gradually smaller.

[0083] Subsequently, at step 421, it is determined whether or not the correction coefficient KK has become smaller than Ko . When $KK > Ko$, the processing cycle is completed, and when KK becomes equal to or smaller than Ko , the processing routine goes to step 422, at which KK is made Ko . Accordingly, after when KK becomes equal to Ko , at the time of the releasing of SO_x , the correction coefficient is maintained at Ko (> 1.0),

while at the time of the releasing of NO_x , the correction coefficient is maintained at 1.0.

[0084] Subsequently, when it is decided at step 419 that C becomes equal to or larger than C_2 , the processing routine goes to step 423, at which it is determined whether or not the SO_x releasing flag has been set. When the SO_x releasing flag has been set, the processing routine goes to step 424, at which the SO_x releasing flag is reset. When the SO_x releasing flag is reset, as will be mentioned later, the combustion of the lean air-fuel mixture is started again. Subsequently, at step 425, the amount W_s of the SO_x absorbed in the SO_x absorption 18 is made zero, and then at step 427, the amount W_n of the NO_x absorbed in the NO_x absorption 19 is made zero. Subsequently, at step 428, the count value C is made zero.

[0085] On the other hand, at step 423, when it is decided that the SO_x releasing flag has not been set, the processing routine goes to step 426, at which the NO_x releasing flag is reset. When the NO_x releasing flag is reset, as will be mentioned later, the combustion of the lean air-fuel mixture is started again. Subsequently, at step 427, the amount W_n of the NO_x absorbed in the NO_x absorption 19 is made zero. Subsequently, at step 428, the count value C is made zero.

[0086] On the other hand, when it is decided at step 50 that K is equal to or larger than 1.0, that is, when the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is the stoichiometric air-fuel ratio or rich, the processing routine goes to step 429, at which it is determined whether or not the state of $K \geq 1.0$ continues for the predetermined time t_1 , for example 10 seconds. When the state of $K \geq 1.0$ does not continue for the predetermined time t_1 , the processing cycle is completed, and when the state of $K \geq 1.0$ continues for the predetermined time t_1 , the processing routine goes to step 430, at which W_n is made zero. Namely, when the time for which air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made the stoichiometric air-fuel ratio or rich continues for about 10 seconds, it is considered that the most part of the NO_x absorbed in the NO_x absorbent 19 was released, and accordingly, in this case, W_n is made zero at step 430.

[0087] Subsequently, at step 431, it is determined whether or not the state of $K > 1.0$ continues for the predetermined time t_2 ($t_2 > t_1$), for example, 10 minutes. When the state of $K > 1.0$ does not continue for the predetermined time t_2 , the processing cycle is completed, and when the state of $K > 1.0$ continues for the predetermined time t_2 , the processing routine goes to step 432, at which W_s is made zero. Namely, when the time for which air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made rich continues for about 10 minutes, it is considered that the most part of the SO_x absorbed in the SO_x absorbent 18 was released, and accordingly, in this case, W_s is made zero at step 432.

[0088] Figure 22 shows the calculation routine of the basic fuel injection time TAU, which routine is repeatedly

executed.

[0089] Referring to Fig. 22, first of all, at step 500, the correction coefficient K is calculated. This correction coefficient K is made for example 0.6 at the time of an operation state when the lean air-fuel mixture should be burned. Also, this correction coefficient K has become the function of the engine coolant temperature at the time of the engine warm-up operation and is made smaller as the engine coolant temperature becomes higher within a range where $K \geq 1.0$. Also, at the time of acceleration operation, this correction coefficient is made 1.0, and at the time of full load operation, this correction coefficient K is made a larger value than 1.0.

[0090] Subsequently, at step 501, it is determined whether or not the correction coefficient K is smaller than 1.0. When $K \geq 1.0$, the processing routine goes to step 505, at which K is made K_t . Contrary to this, when $K < 1.0$, the processing routine goes to step 502, at which it is determined whether or not the SO_x releasing flag has been set. When the SO_x releasing flag has not been set, the processing routine goes to step 503, at which it is determined whether or not the NO_x releasing flag has been set. When the NO_x releasing flag has not been set, the processing routine goes to step 505. Subsequently, at step 506, the basic fuel injection time TP is calculated from the map shown in Fig. 2, and then at step 507, the basic fuel injection time TAU (= $TP \cdot K_t$) is calculated. Accordingly, when neither of the SO_x releasing flag nor NO_x releasing flag has been set even when $K \geq 1.0$ or $K < 1.0$, the air-fuel ratio of the air-fuel mixture is made the air-fuel ratio in accordance with the correction coefficient K.

[0091] On the other hand, when the SO_x releasing flag or the NO_x releasing flag is set, the processing routine goes from step 502 or step 503 to step 504, at which K_t is made K_K calculated by the routine shown in Fig. 20 and Fig. 21. Subsequently, the processing routine passes step 506, and the basic fuel injection time TAU is calculated at step 507. Accordingly, at this time, the air-fuel ratio of the air-fuel mixture is forcibly made rich.

[0092] Figure 23 shows a still further embodiment. Note that, in this embodiment, the same constituent elements as those shown in Fig. 1 and Fig. 12 are indicated by the same symbols.

[0093] Referring to Fig. 23, in this embodiment, the exhaust port 8 is connected via the exhaust manifold 16 to the casing 23 containing the SO_x absorbent 18, and the outlet portion of the casing 23 is connected via the exhaust pipe 17 to the casing 20 containing the NO_x absorbent 19. A bypass passage 24 is branched from the inlet portion 20a of the casing 20, and this bypass passage 24 is connected to the exhaust pipe 25 connected to the outlet portion of the casing 20. A switch valve 27 controlled by an actuator 26 is arranged at the branch portion of the bypass passage 24 from the inlet portion 20a of the casing 20. This switch valve 27 is controlled by the actuator 26 to either position between a bypass closed position at which the inlet portion of the bypass

passage 24 is closed and the inlet portion to the NO_x absorbent 19 is fully opened as indicated by the solid line in Fig. 23 and a bypass opening position at which the inlet portion to the NO_x absorbent 19 is closed and the inlet portion of the bypass passage 24 is fully opened as indicated by a broken line of Fig. 23.

- [0094] Also, in this embodiment, a pressure sensor 28 generating an output voltage in proportion to the absolute pressure in the surge tank 10 is attached to the interior of the surge tank 10, and the output voltage of this pressure sensor 28 is input to the input port 35 via the AD converter 37.
- [0095] Also in this embodiment, the fuel injection time TAU is calculated based on for example the following equation.

$$\text{TAU} = \text{TP} \cdot K$$

- [0096] Here, TP indicates the basic fuel injection time, and K indicates the correction coefficient. The basic fuel injection time TP indicates a fuel injection time necessary for making the air-fuel ratio of the air-fuel mixture fed into the engine cylinder the stoichiometric air-fuel ratio. This basic fuel injection time TP is found in advance by experiments and stored in advance in the ROM 32 in the form of a map as shown in Fig. 24 as the functions of the absolute pressure PM of the surge tank 10 expressing the engine load and the engine rotational speed N. The correction coefficient K is a coefficient for controlling the air-fuel ratio of the air-fuel mixture fed into the engine cylinder, and if $K = 1.0$, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder becomes the stoichiometric air-fuel ratio. Contrary to this, when K becomes smaller than 1.0, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder becomes larger than the stoichiometric air-fuel ratio, that is, becomes lean, and if K becomes larger than 1.0, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder becomes smaller than the stoichiometric air-fuel ratio, that is, becomes rich.
- [0097] The value of this correction coefficient K is determined in advance with respect to the absolute pressure PM in the surge tank 10 and the engine rotational speed N, and Fig. 25 shows one embodiment of the value of this correction coefficient K. In the embodiment shown in Fig. 25, in a region in which the absolute pressure PM inside the surge tank 10 is relatively low, that is, in the engine low or medium load operation region, the value of the correction coefficient K is made a value smaller than 1.0, and accordingly, at this time, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made lean. On the other hand, in a region in which the absolute pressure PM inside the surge tank 10 is relatively high, that is, in the engine high load operation region, the value of the correction coefficient K is made 1.0, and accordingly, at this time, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder

is made the stoichiometric air-fuel ratio. Also, in a region in which the absolute pressure PM inside the surge tank 10 becomes the highest, that is, in the engine full load operation region, the value of the correction coefficient K is made a value larger than 1.0, and accordingly, at this time, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made rich. In the internal combustion engine, usually the frequency of low and medium load operation is the highest, and accordingly in the most part of the operation period, the lean air-fuel mixture will be burned.

[0098] Also in this embodiment, as the SO_x absorbent 18, use is made of an absorbent which carries at least one member selected from a transition metal such as copper Cu, iron Fe, manganese Mn, and nickel Ni, sodium Na, tin Sn, titanium Ti, and lithium Li on a carrier made of alumina. Note that, in this SO_x absorbent 18, as mentioned before, when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 is lean, the SO_2 contained in the exhaust gas is oxidized on the surface of the absorbent while absorbed into the absorbent in the form of sulfuric acid ion SO_4^{2-} , and in this case, when the platinum Pt is carried on the carrier of the SO_x absorbent 18, SO_2 becomes easily adhered onto the platinum Pt in the form of SO_3^{2-} , and thus the SO_2 becomes easily absorbed into the absorbent in the form of the sulfuric acid ion SO_4^{2-} . Accordingly, so as to promote the absorption of the SO_2 , preferably the platinum Pt is carried on the carrier of the SO_x absorbent 18.

[0099] Next, a detailed explanation will be made again of the NO_x releasing function from the NO_x absorbent 19 and the SO_x releasing function from the SO_x absorbent 18 referring to Figs. 26A and 26B. Figure 26A shows a relationship between the temperature T of the NO_x absorbent 19 and the SO_x absorbent 18 when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent 18 and the NO_x absorbent 19 is made rich, the NO_x releasing rate f(T) from the NO_x absorbent 19, and the SO_x releasing rate g(T) from the SO_x absorbent 18, and Fig. 26B shows a relationship between the correction coefficient Kt with respect to the basic fuel injection time TP (stoichiometric air-fuel ratio when Kt = 1.0, rich when Kt > 1.0, and lean when Kt < 1.0), the NO_x releasing rate f(Kt) from the NO_x absorbent 19, and the SO_x releasing rate g(Kt) from the SO_x absorbent 18.

[0100] In the NO_x absorbent 19, when the temperature of the NO_x absorbent 19 is almost 150°C or more, when the NO_2 on the surface of the platinum Pt no longer exists, the reaction is immediately advanced to the direction of $(\text{NO}_3^- \rightarrow \text{NO}_2)$, and the NO_x is immediately released from the absorbent. Accordingly, as shown in Fig. 26A, even if the temperature of the NO_x absorbent 19 is considerably low, the NO_x releasing rate f(T) becomes considerably high. Namely, this means that NO_x is released from the NO_x absorbent 19 at a considerably high speed. Note that, as shown in Fig. 26A, as the temperature T of the NO_x absorbent 19 becomes higher, the NO_x releasing rate f(T) becomes higher, and as shown

in Fig. 26B, as the value of the correction coefficient Kt becomes larger, that is, the degree of richness of the air-fuel ratio of the exhaust gas becomes higher, the NO_x releasing rate f(Kt) becomes higher.

- 5 [0101] Contrary to this, the SO_x absorbed in the SO_x absorbent 18 is stable in comparison with the NO_x absorbed in the NO_x absorbent 19, and therefore is difficult to be decomposed, and the decomposition of this SO_x is not sufficiently caused unless the temperature T of the SO_x absorbent 18 exceeds the temperature To determined according to the type of the SO_x absorbent 18. Accordingly, as shown in Fig. 26A, when the temperature T of the SO_x absorbent 18 is lower than To, the SO_x releasing rate g(T) is extremely low, that is, almost no SO_x is released from the SO_x absorbent 18, and if the temperature T of the SO_x absorbent 18 exceeds To, the SO_x releasing function from the SO_x absorbent 18 is substantially started. Note that, also for SO_x , when the temperature T of the SO_x absorbent 18 exceeds To, as shown in Fig. 26A, as the temperature T of the SO_x absorbent 18 becomes higher, the SO_x releasing rate g(T) becomes higher, and as shown in Fig. 26B, as the value of the correction coefficient Kt becomes larger, the SO_x releasing rate g(Kt) becomes higher.
- 10 [0102] Figure 27A shows the cumulative NO_x release from the NO_x absorbent 19 and the cumulative SO_x release from the SO_x absorbent 18 when the air-fuel ratio of the inflowing exhaust gas to the NO_x absorbent 19 and the SO_x absorbent 18 is made rich when the temperature T of the NO_x absorbent 19 and the SO_x absorbent 18 is lower than To (Fig. 26A); and a solid line of Fig. 27B shows the cumulative NO_x release from the NO_x absorbent 19 and the cumulative SO_x release from the SO_x absorbent 18 When the air-fuel ratio of the inflowing exhaust gas to the NO_x absorbent 19 and the SO_x absorbent 18 is made rich when the temperature T of the NO_x absorbent 19 and the SO_x absorbent 18 is higher than To (Fig. 26A).
- 15 [0103] When the temperature T of the SO_x absorbent 18 is lower than To, as shown in Fig. 26A, almost no SO_x is released, and accordingly, at this time, when the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent 19 and the SO_x absorbent 18 is made rich, as shown in Fig. 27A, the NO_x is quickly released from the NO_x absorbent 19, but almost no SO_x is released from the SO_x absorbent 18.
- 20 [0104] On the other hand, when the temperature T of the SO_x absorbent 18 becomes higher than To, as shown in Fig. 26A, the SO_x releasing function is carried out, and therefore, at this time, if the air-fuel ratio of the exhaust gas flowing into the the NO_x absorbent 19 and the SO_x absorbent 18 is made rich, as indicated by the solid line in Fig. 27B, both of the NO_x and SO_x are released. In this case, the NO_x is released from the NO_x absorbent 19 in a short time, but the decomposition rate of SO_x in the SO_x absorbent 18 is low, and therefore the SO_x is released from the SO_x absorbent 18 only slowly. Note that, also in this case, when the temperature T of

the SO_x absorbent 18 becomes high, as seen from Fig. 26A, the SO_x releasing rate $g(T)$ becomes high, and therefore, as indicated by a broken line in Fig. 27B, the SO_x is released from the SO_x absorbent 18 relatively fast.

[0105] Also, the NO_x release indicated by the solid line in Fig. 27B shows the NO_x release from the SO_x absorbent 18 in which a transition metal such as copper Cu, iron Fe, manganese Mn, nickel Ni, or the like, sodium Na, or lithium Li or the like is carried on the carrier made of alumina, and in the SO_x absorbent 18 in which for example titania TiO_2 is carried on a carrier made of alumina, as indicated by the broken line in Fig. 27B, SO_x is released from the SO_x absorbent 18 relatively fast. In this way the SO_x releasing speed from the SO_x absorbent 18 changes also according to the type of the SO_x absorbent 18, and changes also according to the temperature T of the SO_x absorbent 18.

[0106] As mentioned before, if the air-fuel ratio of the exhaust gas flowing into the the SO_x absorbent 18 and the NO_x absorbent 19 is made rich when the temperature T of the SO_x absorbent 17 is higher than T_0 , the SO_x is released from the SO_x absorbent 18, and the NO_x is released from the NO_x absorbent 19. At this time, if the exhaust gas flowing out from the SO_x absorbent 18 is made to flow into the NO_x absorbent 19, as mentioned before, the SO_x released from the SO_x absorbent 18 is absorbed into the NO_x absorbent 19. Therefore, in this embodiment, so as to prevent the SO_x released from the SO_x absorbent 18 from absorption into the NO_x absorbent 19 in this way, when the SO_x absorbent 18 should release the SO_x , the exhaust gas flowing out of the SO_x absorbent 18 is guided into the bypass passage 24.

[0107] Namely, in this embodiment, when the lean air-fuel mixture is burned, the switch valve 27 is held at the bypass closed position indicated by the solid line in Fig. 23, and accordingly, at this time, the exhaust gas flowing out of the SO_x absorbent 18 flows into the NO_x absorbent 19. Accordingly, at this time, the SO_x in the exhaust gas is absorbed by the SO_x absorbent 18, and therefore only the NO_x is absorbed into the NO_x absorbent 19. Subsequently, when the SO_x from the SO_x absorbent 18 should be released, as shown in Fig. 28, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is switched from lean to rich, and simultaneously the switch valve 27 is switched to the bypass opening position indicated by the broken line in Fig. 23. When the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes rich, as shown in Fig. 28, SO_x is released from the SO_x absorbent 18, but at this time, the flowing out exhaust gas from the SO_x absorbent 18 does not flowing into the NO_x absorbent 19, but flows into the bypass passage 24.

[0108] Subsequently, when the releasing action of the SO_x should be stopped, the air-fuel ratio of the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is switched from rich to lean, and simultane-

ously the switch valve 27 is switched to the bypass closed position indicated by the solid line in Fig. 23. When the air-fuel ratio of the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes lean, as shown in Fig. 28, the releasing action of SO_x from the SO_x absorbent 18 is stopped.

[0109] In this way, in the embodiment shown in Fig. 28, when the SO_x is being released from the SO_x absorbent 18, the exhaust gas flowing out of the SO_x absorbent 18 flows into the bypass passage 24, and therefore it becomes possible to prevent the SO_x from absorption into the NO_x absorbent 19. Note that, at this time, the unburnt HC and CO and NO_x are discharged from the engine, but as mentioned before, the SO_x absorbent 18 has a three-way catalytic function, and therefore these unburnt HC and CO and NO_x are considerably removed at the SO_x absorbent 18, and accordingly, at this time, there is no risk of releasing of a large amount of unburnt HC and CO and NO_x into the atmosphere.

[0110] Figure 29 and Fig. 30 show respectively different embodiments in which when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich so as to release the SO_x from the SO_x absorbent 18, the releasing action of the NO_x from the NO_x absorbent 19 is carried out together with the former.

[0111] The embodiment shown in Fig. 29 shows the SO_x and NO_x releasing control which can be applied to a case where the SO_x releasing speed from the SO_x absorbent 18 is considerably slower in comparison with the NO_x releasing speed from the NO_x absorbent 19. As indicated by the solid line in Fig. 27B, where the SO_x releasing speed is slower in comparison with the NO_x releasing speed, when the air-fuel ratio of the exhaust gas flowing into the the SO_x absorbent 18 and the NO_x absorbent 19 is switched from lean to rich, the NO_x is released from the NO_x absorbent 19 in a short time, and in addition during a time when the releasing action of NO_x is carried out, almost no SO_x is released from the SO_x absorbent 18. Accordingly, in this embodiment, during a predetermined period after when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is switched from lean to rich ($K_t = KK1$) (a period for which $K_t = KK1$ is maintained in Fig. 29), the switch valve 27 is held at the bypass closed position, and then when

45 this predetermined period has elapsed, the switch valve 27 is switched to the bypass opening position. For the predetermined period after this (period for which $K_t = KK2$ is maintained), the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is maintained rich ($K_t = KK2$), and when this predetermined period has elapsed, the switch valve 27 is switched to the bypass closed position.

[0112] In this way, in this embodiment; in an initial stage when the air-fuel ratio of the air-fuel mixture is switched from lean to rich, the switch valve 27 is held at the bypass closed position, and therefore the NO_x is rapidly released from the NO_x absorbent 19. At this time, the releasing of the SO_x is started also from the SO_x

absorbent 18, but the release of SO_x is small, and accordingly, even if this SO_x is absorbed into the NO_x absorbent 19, the amount of absorption of SO_x is not so much increased. The most part of the SO_x is released from the SO_x absorbent 18 after the switch valve 27 is switched to the bypass closed position, and accordingly the most part of the SO_x is fed into the bypass passage 24.

[0113] The embodiment shown in Fig. 30 shows the SO_x and NO_x releasing control controlled so as to prevent the SO_x from absorption into the NO_x absorbent 19 as much as possible. In this embodiment, when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, the switch valve 27 is switched to the bypass closed position. At this time, the releasing of the SO_x is started from the SO_x absorbent 18, and this SO_x is all fed into the bypass passage 24. Subsequently, when the releasing action of the SO_x from the SO_x absorbent 18 is almost completed, the switch valve 27 is switched to the bypass closed position while maintaining the air-fuel ratio of the air-fuel mixture rich. When the switch valve 27 is switched to the bypass closed position, the NO_x is rapidly released from the NO_x absorbent 19, and when the releasing action of NO_x from the NO_x absorbent 19 is completed, the air-fuel ratio of the air-fuel mixture is switched from rich to lean.

[0114] In this embodiment, after the SO_x releasing action from the SO_x absorbent 18 is completely terminated, if the switch valve 27 is switched from the bypass opening position to the bypass closed position, it is possible to completely prevent the SO_x from absorption into the NO_x absorbent 19.

[0115] Note that, even in a case where the releasing speed of the SO_x from the SO_x absorbent 18 is slow as indicated by the solid line in Fig. 27B, when the temperature of the SO_x absorbent 18 becomes high, as mentioned before, the SO_x releasing speed becomes faster. In this way, when the SO_x and NO_x releasing action as shown in Fig. 29 is carried out when the SO_x releasing speed becomes faster, immediately after the air-fuel ratio of the air-fuel mixture is switched from lean to rich, a large amount of the SO_x is released also from the SO_x absorbent 18, and thus a large amount of the SO_x becomes absorbed into the NO_x absorbent 19. Therefore, in another embodiment according to the present invention, when the temperature of the SO_x absorbent 18 is relatively low and the releasing speed of SO_x is slow, the releasing control of the SO_x and NO_x shown in Fig. 29 is carried out, and when the temperature of the SO_x absorbent 18 becomes high and the releasing speed of SO_x becomes faster, the releasing control of the SO_x and NO_x shown in Fig. 30 is carried out.

[0116] Figure 31 shows the releasing control timing of the NO_x and SO_x . Note that, this Fig. 31 shows a case using the embodiment shown in Fig. 29 as the SO_x releasing control. Also, in Fig. 31, P indicates the NO_x releasing control, and Q indicates the NO_x and SO_x releasing control.

[0117] In the embodiment shown in Fig. 31, the releasing processing of the NO_x and SO_x is carried out based on the NO_x amount W_n and the SO_x amount W_s . In this case, as the amount W_n of NO_x absorbed in the NO_x absorbent 19 and the amount W_s of SO_x absorbed in the SO_x absorbent 18, an estimated absorption amount estimated from the operation state of the engine is used. This NO_x amount W_n and SO_x amount W_s will be mentioned later.

[0118] As shown in Fig. 31, when the NO_x amount W_n exceeds the maximum allowable value W_{no} , the air-fuel ratio of the air-fuel mixture is made rich ($K_t = KK1$), and the releasing action of NO_x from the NO_x absorbent 19 is started. When the releasing action of NO_x is started, the NO_x amount W_n is rapidly reduced, and when the NO_x amount W_n reaches the lower limit value MIN , the air-fuel ratio of the air-fuel mixture is switched from rich to lean, and the releasing action of NO_x is stopped. Contrary to this, when the SO_x amount W_s exceeds the maximum allowable value W_{so} , the air-fuel ratio of the air-fuel mixture is made rich ($K_t = KK1$) for a predetermined period, and the releasing action of NO_x from the NO_x absorbent 19 is started. At this time, also the releasing action of SO_x from the SO_x absorbent 18 is started. Subsequently, when the NO_x amount W_n reaches the lower limit value MIN , the switch valve 27 is switched to the bypass opening position. Subsequently, when the SO_x amount W_s reaches the lower limit value MIN , the air-fuel ratio of the air-fuel mixture is switched from rich to lean, and the releasing action of SO_x is stopped.

[0119] Note that, as seen from Fig. 31, the period of making the air-fuel ratio of the air-fuel mixture rich so as to release the NO_x from the NO_x absorbent 19 is considerably short, and the air-fuel ratio of the air-fuel mixture is made rich with a proportion of one time per several minutes. On the other hand, as mentioned before, the amount of SO_x contained in the exhaust gas is considerably smaller than the amount of NO_x , and therefore a considerably long time is taken until the SO_x absorbent 18 is saturated by the SO_x . Accordingly, the period of making the air-fuel ratio of the air-fuel mixture rich so as to release the SO_x from the SO_x absorbent 18 is considerably short, and the air-fuel ratio of the air-fuel mixture is made rich with a proportion of for example one time per several hours.

[0120] Figures 32A to 32D show the flag switch valve control routine for executing the NO_x and SO_x releasing control shown in Fig. 28, which routine is executed by the interruption at every predetermined time interval.

[0121] Referring to Figs. 32A to 32D, first of all, at step 600 to step 608, the amount W_n of NO_x absorbed in the NO_x absorbent 19 and the amount W_s of SO_x absorbed in the SO_x absorbent 18 are calculated. Namely, first of all, at step 600, it is determined whether or not the correction coefficient K_t with respect to the basic fuel injection time TP is smaller than 1.0. When $K_t < 1.0$, that is, when the lean air-fuel mixture is fed into the combustion chamber 3, the processing routine goes to step 601, at

which the NO_x amount W_n is calculated based on the following equation, and then the processing routine goes to step 602, at which the SO_x amount W_s is calculated based on the following equation.

$$W_n = W_n + K_1 \cdot N \cdot PM$$

$$W_s = W_s + K_2 \cdot N \cdot PM$$

[0122] Here, N indicates the engine rotational speed; PM indicates the absolute pressure in the surge tank 10; and K_1 and K_2 indicate constants ($K_1 > K_2$). The amount of the NO_x and amount of SO_x discharged from the engine per unit time are in proportion to the engine rotational speed N and in proportion to the absolute pressure PM in the surge tank 10, and therefore the NO_x amount W_n and the SO_x amount W_s are represented as in the above equations. Accordingly, it is seen from these equations that so far as the combustion of the lean air-fuel mixture is continued, the NO_x amount W_n and the SO_x amount W_s are increased. When the NO_x amount W_n is calculated at step 601, and the SO_x amount W_s is calculated at step 602, the processing routine goes to step 609.

[0123] On the other hand, when it is determined at step 600 that $Kt \geq 1.0$, that is, when air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is the stoichiometric air-fuel ratio or rich, the processing routine goes to step 603, at which the NO_x amount W_n is calculated based on the following equation, and then the processing routine goes to step 604, at which the SO_x amount W_s is calculated based on the following equation:

$$W_n = W_n - W_n \cdot f(T) \cdot f(Kt)$$

$$W_s = W_s - W_s \cdot g(T) \cdot g(Kt)$$

[0124] Here, $f(T)$ and $g(T)$ indicate the NO_x releasing rate and the SO_x releasing rate shown in Fig. 26A, respectively, and $f(Kt)$ and $g(Kt)$ indicate the NO_x releasing rate and the SO_x releasing rate shown in Fig. 26B, respectively. As shown in Fig. 26A, the NO_x releasing rate $f(T)$ and the SO_x releasing rate $g(T)$ are functions of the exhaust gas temperature T , and accordingly these NO_x releasing rate $f(T)$ and SO_x releasing rate $g(T)$ are calculated from the exhaust gas temperature T detected by the temperature sensor 22. Note that, it is also possible to directly detect the exhaust gas temperature T by the temperature sensor 22 in this way, but it is also possible to estimate the same from the absolute pressure PM in the surge tank 10 and the engine rotational speed N . In this case, it is sufficient if the relationship among the exhaust gas temperature T , the absolute

pressure PM , and the engine rotational speed N is found in advance by experiments, this relationship is stored in advance in the ROM 32 in the form of the map as shown in Fig. 33, and the exhaust gas temperature T is calculated from this map.

[0125] Also, as shown in Fig. 26B, the NO_x releasing rate $f(Kt)$ and SO_x releasing rate $g(Kt)$ are functions of the correction coefficient Kt , and accordingly the NO_x releasing rate $f(Kt)$ and SO_x releasing rate $g(Kt)$ are calculated from the correction coefficient Kt . An actual NO_x releasing rate is expressed by the product of the $f(T)$ and the $f(Kt)$, and therefore this means that the amount of NO_x released from the NO_x absorbent 19 per unit time is expressed by $W_n \cdot f(T) \cdot f(Kt)$, and accordingly the amount W_n of NO_x absorbed in the NO_x absorbent 19 becomes like the above-mentioned equation. Similarly, the SO_x releasing rate is expressed by the product of the $g(T)$ and the $g(Kt)$, and therefore this means that the amount of SO_x released from the SO_x absorbent 18 per unit time is expressed by $W_s \cdot g(T) \cdot g(Kt)$, and accordingly the amount W_s of SO_x absorbed in the SO_x absorbent 18 becomes like the above-mentioned equation. Accordingly, it is seen that both of the NO_x amount W_n and the SO_x amount W_s are reduced when $Kt \geq 1.0$. Note that, the NO_x amount W_n and the SO_x amount W_s calculated at step 601 to step 604 is stored in the backup RAM 33a.

[0126] When the NO_x amount W_n is calculated at step 603 and the SO_x amount W_s is calculated at step 604, the processing routine goes to step 605, at which it is determined whether or not the NO_x amount W_n becomes negative. When $W_n < 0$, the processing routine goes to step 606, at which W_n is made zero, and then the processing routine goes to step 607. At step 607, it is determined whether or not the SO_x amount W_s becomes negative. When $W_s < 0$, the processing routine goes to step 608, at which W_s is made zero, and then the processing routine goes to step 609.

[0127] At step 609, it is determined whether or not the correction coefficient K determined according to the engine rotation state shown in Fig. 25 is smaller than 1.0. When $K < 1.0$, that is, when the target air-fuel ratio determined according to the operation state of the engine is lean, the processing routine goes to step 610, at which it is determined whether or not the SO_x processing has been set. When the SO_x processing flag has not been set, the routine jumps to step 613, at which it is determined whether or not the SO_x releasing flag has been set. When the SO_x releasing flag has not been set, the processing routine goes to step 614, at which it is determined whether or not the NO_x releasing flag has been set. When the NO_x releasing flag has not been set, the processing routine goes to step 615.

[0128] At step 615, it is determined whether or not the SO_x amount W_s has become larger than the maximum allowable value W_{so} (Fig. 31). When $W_s \leq W_{so}$, the processing routine goes to step 616, at which it is determined whether or not the NO_x amount W_n has be-

come larger than the maximum allowable value W_{no} . When $W_n \leq W_{no}$, the processing cycle is completed. At this time, the lean air-fuel mixture is fed into the combustion chamber 3, and the switch valve 27 is held at the bypass closed position.

[0129] On the other hand, when it is determined at step 616 that the W_n becomes larger than W_{no} , the processing routine goes to step 617, at which the NO_x releasing flag is set, and then the processing cycle is completed. In the next processing cycle, it is determined at step 614 that the NO_x releasing flag has been set, and therefore the processing routine goes to step 618, at which the correction coefficient K_t is made $KK1$. The value of this $KK1$ is a value of about 1.1 to 1.2 with which the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes about 12.0 to 13.5. When K_t is made $KK1$, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich. Subsequently, at step 619, it is determined whether or not the NO_x amount W_n has become smaller than the lower limit value MIN (Fig. 31), and when $W_n \geq MIN$, the processing cycle is completed. Contrary to this, when W_n becomes smaller than MIN , the processing routine goes to step 620, at which the NO_x releasing flag is set. When the NO_x releasing flag is reset, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is switched from rich to lean. Accordingly, during a period from when W_n becomes larger than W_{no} to when W_n becomes smaller than MIN , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, and during this time, the NO_x is released from the NO_x absorbent 19.

[0130] On the other hand, when it is decided at step 615 that the SO_x amount W_s has become larger than the maximum allowable value W_{so} , the processing routine goes to step 621, at which it is determined whether or not the temperature T of exhaust gas flowing into the SO_x absorbent 18 is higher than the set value To (Fig. 26A). When $T \leq To$, the processing cycle is completed. Contrary to this, when $T > To$, the processing routine goes to step 622, at which the SO_x releasing flag is set and then the processing cycle is completed.

[0131] In the next processing cycle, it is decided at step 613 that the SO_x releasing flag has been set, and therefore the processing routine goes to step 623, at which the correction coefficient K_t is made $KK2$. The value of this $KK2$ is the value of about 1.1 to 1.2 with which the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes about 12.0 to 13.5. It is also possible to make the value of this $KK2$ different from the value of $KK1$, and make the same as the same value as the value of $KK1$. When the correction coefficient K_t is made $KK2$, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich. Subsequently, at step 624, the switch valve 27 is switched to the bypass opening position, and thus the exhaust gas flowing out of the SO_x absorbent 18 is fed into the bypass passage 24.

[0132] Subsequently, at step 625, it is determined whether or not the SO_x amount W_s has become smaller than the lower limit value MIN , and when $W_s \geq MIN$, the processing cycle is completed. Contrary to this, when

5 W_s becomes smaller than MIN , the processing routine goes to step 626, at which the switch valve 27 is switched to the bypass closed position, and then the processing routine goes to step 627, at which the SO_x releasing flag is reset. When the SO_x releasing flag is reset, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is switched from rich to lean. Accordingly, when W_s becomes larger than W_{so} , if $T > To$, from when the W_s becomes larger than W_{so} to when W_s becomes smaller than MIN , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich and, at the same time, the switch valve 27 is held at the bypass opening position. Thus, during this term, the SO_x is released from the SO_x absorbent 18, and the released SO_x is fed into the bypass passage 24.

[0133] On the other hand, when it is determined at step 609 that $K \geq 1.0$, that is, when the target air-fuel ratio of the air-fuel mixture which should be fed into the combustion chamber 3 becomes the stoichiometric air-fuel ratio or rich, the processing routine goes to step 628,

20 25 at which the NO_x releasing flag is reset, and then the processing routine goes to step 629, at which the SO_x releasing flag is reset. Subsequently, at step 630, the switch valve control shown in Fig. 32D is carried out. In this switch valve control, as shown in Fig. 32D, first of all, it is determined at step 631 whether or not the SO_x processing flag has been set. When the SO_x flag has not been set, the processing routine goes to step 632,

30 35 at which it is determined whether or not the SO_x amount W_s is larger than the set up value W_k ($MIN < W_k < W_{so}$). When $W_s \leq W_k$, the processing routine goes to step 634, at which the switch valve 27 is made the bypass closed position. When $W_s \leq W_k$ even if the SO_x is released from the SO_x absorbent 18, since the SO_x release is small, the switch valve 27 is made the bypass closed position.

[0134] Contrary to this, when $W_s > W_k$, the processing routine goes to step 633, at which it is determined whether or not the temperature T of exhaust gas flowing into the SO_x absorbent 18 is higher than the set value To (Fig. 26A). When $T \leq To$, the processing routine goes to step 634. Namely, when $T \leq To$, almost no SO_x is released from the SO_x absorbent 18, and therefore the switch valve 27 is made the bypass closed position. Note that, the NO_x is released from the NO_x absorbent 19 when the switch valve 27 is held at the bypass closed position.

[0135] On the other hand, when it is decided at step 633 that $T > To$, the processing routine goes to step 635, at which the SO_x processing flag is set. When the SO_x processing flag is set, the processing routine goes from step 631 to step 633, at which the switch valve 27 is switched to the bypass opening position. Namely, when $W_s > W_k$ and $T > To$, a certain amount of SO_x is released from the SO_x absorbent 18, and therefore the switch

valve 27 is made the bypass opening position so as to feed the released SO_x into the bypass passage 24. Subsequently, at step 637, it is determined whether or not the amount W_s of SO_x becomes smaller than the lower limit value MIN. When W_s becomes smaller than MIN, the processing routine goes to step 638, at which the SO_x processing flag is reset. When the SO_x processing flag is reset, in the next processing cycle, the processing routine goes from step 631 to step 632, since it is determined that W_s is equal to or smaller than W_k at this time, and therefore the processing routine goes to step 634, at which the switch valve 27 is switched to the bypass closed position.

[0136] On the other hand, where the SO_x flag has been set when the operation state is changed from the state where $K \geq 1.0$ to the state where $K < 1.0$, the processing routine goes from step 610 to step 611, at which the SO_x processing flag is reset. Subsequently, at step 612, the switch valve 27 is switched to the bypass closed position.

[0137] Figure 34 shows the calculation routine of the fuel injection time TAU, which routine is repeatedly executed.

[0138] Referring to Fig. 34, first of all, at step 650, the correction coefficient K determined in accordance with the engine operation state shown in Fig. 25 is calculated. Subsequently, at step 651, the basic fuel injection time TP is calculated from the map shown in Fig. 2. Subsequently, at step 652, it is determined whether or not the NO_x releasing flag has been set, and when the NO_x releasing flag has not been set, the processing routine goes to step 653, at which it is determined whether or not the SO_x releasing flag has been set. When the SO_x releasing flag has not been set, the processing routine goes to step 654, at which the correction coefficient K is made K_t , and then at step 655, the fuel injection time TAU ($= TP \cdot K_t$) is calculated by multiplying the basic fuel injection time TP by K_t . Accordingly, when the NO_x releasing flag and the SO_x releasing flag have not been set, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes the air-fuel ratio determined by the correction coefficient K.

[0139] Contrary to this, when the NO_x releasing flag is set, the processing routine jumps to step 655, and when the SO_x releasing flag is set, the processing routine goes to step 655. When the NO_x releasing flag is set, in the routine shown in Figs. 32A to 32D, K_t is made equal to KK_1 ($KK_1 > 1.0$), and therefore the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, while when the SO_x releasing flag is set, in the routine shown in Figs. 32A to 32D, K_t is made equal to KK_2 ($KK_2 > 1.0$), and therefore the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich.

[0140] Figures 35A to 35D show the flag switch valve control routine for executing the NO_x and SO_x releasing control shown in Fig. 29, which routine is executed by interruption at every predetermined time interval. Note

that, in this embodiment, the flow chart part shown in Fig. 35A, Fig. 35B, and Fig. 35D is substantially the same as the flow chart part shown in Fig. 32A, Fig. 32B, and Fig. 32D, and the part which is basically different from them is only the flow chart part shown in Fig. 35C.

[0141] Namely, referring to Figs. 35A to 35D, first of all, at step 700, it is determined whether or not the correction coefficient K_t with respect to the basic fuel injection time TP is smaller than 1.0. When $K_t < 1.0$, that is, when the lean air-fuel mixture is fed into the combustion chamber 3, the processing routine goes to step 701, at which the NO_x amount W_n ($= W_n + K_1 \cdot N \cdot PM$) is calculated, and then the processing routine goes to step 702, at which the SO_x amount W_s ($= W_s + K_2 \cdot N \cdot PM$) is calculated. Here, N indicates the engine rotational speed, P indicates the absolute pressure in the surge tank 10, and K_1 and K_2 indicate constants ($K_1 > K_2$). Then, the processing routine goes to step 709.

[0142] On the other hand, when it is determined at step 700 that $K_t \geq 1.0$, that is, when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is the stoichiometric air-fuel ratio or rich, the processing routine goes to step 703, at which the NO_x amount W_n ($= W_n - W_n \cdot f(T) \cdot g(K_t)$) is calculated, and then the processing routine goes to step 704, at which the SO_x amount W_s ($= W_s - W_s \cdot g(T) \cdot g(K_t)$) is calculated. Here, $f(T)$ and $g(T)$ indicate the NO_x releasing rate and SO_x releasing rate shown in Fig. 26A, respectively, and $f(K_t)$ and $g(K_t)$ indicate the NO_x releasing rate and SO_x releasing rate shown in Fig. 26B, respectively.

[0143] When the NO_x amount W_n is calculated at step 703, and the SO_x amount W_s is calculated at step 704, the processing routine goes to step 705, at which it is determined whether or not the NO_x amount W_n has become negative. When $W_n < 0$, the processing routine goes to step 706, at which W_n is made zero, and then, the processing routine goes to step 707. At step 707, it is determined whether or not the SO_x amount W_s becomes negative. When $W_s < 0$, the processing routine goes to step 708, at which W_s is made zero, and then the processing routine goes to step 709.

[0144] At step 709, it is determined whether or not the correction coefficient K determined according to the engine operation state shown in Fig. 25 is smaller than 1.0.

[0145] When $K < 1.0$, that is, when the target air-fuel ratio determined according to the operation state of the engine is lean, the processing routine goes to step 710, at which it is determined whether or not the SO_x processing has been set. When the SO_x processing flag has not been set, the routine jumps to step 713, at which it is determined whether or not the SO_x and NO_x releasing flag has been set. When the SO_x and NO_x releasing flag has not been set, the processing routine goes to step 714, at which it is determined whether or not the NO_x releasing flag has been set. When the NO_x releasing flag has not been set, the processing routine goes to step 715.

[0146] At step 715, it is determined whether or not the SO_x amount W_s has become larger than the maximum

allowable value W_{so} (Fig. 31). When $W_s \leq W_{so}$, the processing routine goes to step 716, at which it is determined whether or not the NO_x amount W_n has become larger than the maximum allowable value W_{ho} . When $W_n \leq W_{ho}$, the processing cycle is completed. At this time, the lean air-fuel mixture is fed into the combustion chamber 3, and the switch valve 27 is held at the bypass closed position.

[0146] On the other hand, when it is determined at step 716 that the W_n becomes larger than W_{ho} , the processing routine goes to step 717, at which the NO_x releasing flag is set, and then the processing cycle is completed. In the next processing cycle, it is determined at step 714 that the NO_x releasing flag has been set, and therefore the processing routine goes to step 718, at which the correction coefficient K_t is made $KK1$. The value of this $KK1$ is a value of about 1.1 to 1.2 with which the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes about 12.0 to 13.5. When K_t is made $KK1$, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich. Subsequently, at step 719, it is determined whether or not the NO_x amount W_n has become smaller than the lower limit value MIN (Fig. 31), and when $W_n \geq MIN$, the processing cycle is completed. Contrary to this, when W_n becomes smaller than MIN , the processing routine goes to step 720, at which the NO_x releasing flag is set. When the NO_x releasing flag is reset, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is switched from rich to lean. Accordingly, during a period from when W_n becomes larger than W_{ho} to when W_n becomes smaller than MIN , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, and during this time, the NO_x is released from the NO_x absorbent 19.

[0147] On the other hand, when it is decided at step 715 that the SO_x amount W_s has become larger than the maximum allowable value W_{so} , the processing routine goes to step 721, at which it is determined whether or not the temperature T of exhaust gas flowing into the SO_x absorbent 18 is higher than the set value T_0 (Fig. 26A). When $T \leq T_0$, the processing cycle is completed. Contrary to this, when $T > T_0$, the processing routine goes to step 722, at which the SO_x and NO_x releasing flag is set and then the processing cycle is completed.

[0148] In the next processing cycle, it is decided at step 713 that the SO_x and NO_x releasing flag has been set, and therefore the processing routine goes to step 723, at which it is determined whether or not the NO_x amount W_n has become smaller than the lower limit value MIN . When $W_n > MIN$, the processing routine goes to step 724, at which the correction coefficient K_t is made $KK1$, and then the processing cycle is completed. Accordingly, when W_s becomes larger than W_{so} , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich ($K_t = KK1$) until when W_n becomes smaller than MIN , and the switch valve 27 is held at the bypass closed position. Accordingly, the NO_x

will be released from the NO_x absorbent 19 during this time.

[0149] On the other hand, when it is decided at step 723 that W_n becomes smaller than MIN , the processing routine goes to step 725, at which the correction coefficient K_t is made $KK2$. The value of this $KK2$ is a value of about 1.1 to 1.2 with which the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes about 12.0 to 13.5. It is also possible to make the value of this $KK2$ different from the value of $KK1$, or make this the same value as the value of $KK1$. When the correction coefficient K_t is made $KK2$, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich. Subsequently, at step 726, the switch valve 27 is switched to the bypass opening position. Thus, the exhaust gas flowing out of the SO_x absorbent 18 is fed into the bypass passage 24.

[0150] Subsequently, at step 727, it is determined whether or not the SO_x amount W_s becomes smaller than the lower limit value MIN , and when $W_s \geq MIN$, the processing cycle is completed. Contrary to this, when W_s becomes smaller than MIN , the processing routine goes to step 728, at which the switch valve 27 is switched to the bypass closed position, and then the processing routine goes to step 729, at which the SO_x and NO_x releasing flag is reset. When the SO_x and NO_x releasing flag is reset, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is switched from rich to lean. Accordingly, if $T > T_0$ when W_s becomes larger than W_{so} , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich ($K_t = KK2$) from when W_n becomes smaller than MIN to when W_s becomes smaller than MIN and, at the same time, the switch valve 27 is made the bypass opening position. Thus, during this time, the SO_x is released from the SO_x absorbent 18, and the released SO_x is fed into the bypass passage 24.

[0151] On the other hand, when it is determined at step 709 that $K \geq 1.0$, that is, when the target air-fuel ratio of the air-fuel mixture which should be fed into the combustion chamber 3 becomes the stoichiometric air-fuel ratio or rich, the processing routine goes to step 730, at which the NO_x releasing flag is reset, and then the processing routine goes to step 731, at which the SO_x and NO_x releasing flag is reset. Subsequently, at step 732, the switch valve control shown in Fig. 35D is carried out. In this switch valve control, as shown in Fig. 35D, first of all, at step 733, it is determined whether or not the SO_x processing flag has been set. When the SO_x processing flag has not been set, the processing routine goes to step 734, at which it is determined whether or not the SO_x amount W_s is larger than the set value W_k ($MIN < W_k < W_{so}$). When $W_s \leq W_k$, the processing routine goes to step 736, at which the switch valve 27 is made the bypass closed position. When $W_s \leq W_k$, even if the SO_x is released from the SO_x absorbent 18, the amount of the released SO_x is small, and therefore the switch valve 27 is made the bypass closed position.

[0152] Contrary to this, when $W_s > W_k$, the processing routine goes to step 735, at which it is determined whether or not the temperature T of exhaust gas flowing into the SO_x absorbent 18 is higher than the set value T_0 (Fig. 26A). When $T \leq T_0$, the processing routine goes to step 736. Namely, when $T \leq T_0$, almost no SO_x is released from the SO_x absorbent 18, and therefore the switch valve 27 is made the bypass closed position. Note that, the NO_x is released from the NO_x absorbent 19 when the switch valve 27 is held at the bypass closed position.

[0153] On the other hand, when it is decided at step 735 that $T > T_0$, the processing routine goes to step 737, at which the SO_x processing flag is set. When the SO_x processing flag is set, the processing routine goes from step 733 to step 738, at which the switch valve 27 is switched to the bypass opening position. Namely, when $W_s > W_k$ and $T > T_0$, a certain amount of the SO_x is released from the SO_x absorbent 18, and therefore the switch valve 27 is made the bypass opening position so as to feed the released SO_x into the bypass passage 24. Subsequently, at step 739, it is determined whether or not the amount W_s of SO_x becomes smaller than the lower limit value MIN. When W_s becomes smaller than MIN, the processing routine goes to step 740, at which the SO_x processing flag is reset. When the SO_x processing flag is reset, in the next processing cycle, the processing routine goes from step 733 to step 734, since it is determined that W_s is equal to or smaller than W_k at this time, and therefore the processing routine goes to step 736, at which the switch valve 27 is switched to the bypass closed position.

[0154] On the other hand, where the SO_x flag has been set when the operation state is changed from the state where $K \geq 1.0$ to the state where $K < 1.0$, the processing routine goes from step 710 to step 711, at which the SO_x processing flag is reset. Subsequently, at step 712, the switch valve 27 is switched to the bypass closed position.

[0155] Figure 36 shows the calculation routine of the fuel injection time TAU , which routine is substantially the same as the routine shown in Fig. 34. Note that, this routine is repeatedly executed.

[0156] Namely, referring to Fig. 36, first of all, at step 750, the correction coefficient K determined in accordance with the engine operation state shown in Fig. 25 is calculated. Subsequently, at step 751, the basic fuel injection time TP is calculated from the map shown in Fig. 2. Subsequently, at step 752, it is determined whether or not the NO_x releasing flag has been set, and when the NO_x releasing flag has not been set, the processing routine goes to step 753, at which it is determined whether or not the SO_x and NO_x releasing flag has been set. When the SO_x and NO_x releasing flag has not been set, the processing routine goes to step 754, at which the correction coefficient K is made K_t , and then at step 755, the fuel injection time TAU ($= TP \cdot K_t$) is calculated by multiplying the basic fuel injection time TP by K_t . Ac-

cordingly, when the NO_x releasing flag and the SO_x and NO_x releasing flag have not been set, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes the air-fuel ratio determined by the correction coefficient K .

[0157] Contrary to this, when the NO_x releasing flag is set, the processing routine jumps to step 755, and when the SO_x and NO_x releasing flag is set, the processing routine goes to step 755. When the NO_x releasing flag is set, in the routine shown in Figs. 35A to 35D, K_t is made equal to KK_1 ($KK_1 > 1.0$), and therefore the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, while when the SO_x and NO_x releasing flag is set, in the routine shown in Figs. 35A to 35D, K_t is made equal to KK_1 ($KK_1 > 1.0$), and then K_t is made equal to KK_2 ($KK_2 > 1.0$), and therefore the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich.

[0158] Figures 37A to 37D show the flag switch valve control routine for executing the NO_x and SO_x releasing control shown in Fig. 30, which routine is executed by interruption at every predetermined time interval. Note that, in this embodiment, the flow chart part shown in Fig. 37A, Fig. 37B, and Fig. 37D is substantially the same as the flow chart part shown in Fig. 32A, Fig. 32B, and Fig. 32D, and the part which is basically different from them is only the flow chart part shown in Fig. 37C.

[0159] Namely, referring to Figs. 37A to 37D, first of all, at step 800, it is determined whether or not the correction coefficient K_t with respect to the basic fuel injection time TP is smaller than 1.0. When $K_t < 1.0$, that is, when the lean air-fuel mixture is fed into the combustion chamber 3, the processing routine goes to step 801, at which the NO_x amount W_n ($= W_n + K_1 \cdot N \cdot PM$) is calculated, and then the processing routine goes to step 802, at which the SO_x amount W_s ($= W_s + K_2 \cdot N \cdot PM$) is calculated. Here, N indicates the engine rotational speed, P indicates the absolute pressure in the surge tank 10, and K_1 and K_2 indicate constants ($K_1 > K_2$).

[0160] Then, the processing routine goes to step 809. On the other hand, when it is determined at step 800 that $K_t \geq 1.0$, that is, when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is the stoichiometric air-fuel ratio or rich, the processing routine goes to step 803, at which the NO_x amount W_n ($= W_n - W_n \cdot f(T) \cdot f(K_t)$) is calculated, and then the processing routine goes to step 804, at which the SO_x amount W_s ($= W_s - W_s \cdot g(T) \cdot g(K_t)$) is calculated. Here, $f(T)$ and $g(T)$ indicate the NO_x releasing rate and SO_x releasing rate shown in Fig. 26A, respectively, and $f(K_t)$ and $g(K_t)$ indicate the NO_x releasing rate and SO_x releasing rate shown in Fig. 26B, respectively.

[0161] When the NO_x amount W_n is calculated at step 803, and the SO_x amount W_s is calculated at step 804, the processing routine goes to step 805, at which it is determined whether or not the NO_x amount W_n has become negative. When $W_n < 0$, the processing routine goes to step 806, at which W_n is made zero, and then,

the processing routine goes to step 807. At step 807, it is determined whether or not the SO_x amount W_s becomes negative. When $W_s < 0$, the processing routine goes to step 808, at which W_s is made zero, and then the processing routine goes to step 809.

[0162] At step 809, it is determined whether or not the correction coefficient K determined according to the engine operation state shown in Fig. 25 is smaller than 1.0. When $K < 1.0$, that is, when the target air-fuel ratio determined according to the operation state of the engine is lean, the processing routine goes to step 810, at which it is determined whether or not the SO_x processing has been set. When the SO_x processing flag has not been set, the routine jumps to step 813, at which it is determined whether or not the SO_x and NO_x releasing flag has been set. When the SO_x and NO_x releasing flag has not been set, the processing routine goes to step 814, at which it is determined whether or not the NO_x releasing flag has been set. When the NO_x releasing flag has not been set, the processing routine goes to step 815.

[0163] At step 815, it is determined whether or not the SO_x amount W_s has become larger than the maximum allowable value W_{so} (Fig. 31). When $W_s \leq W_{so}$, the processing routine goes to step 816, at which it is determined whether or not the NO_x amount W_n has become larger than the maximum allowable value W_{no} . When $W_n \leq W_{no}$, the processing cycle is completed. At this time, the lean air-fuel mixture is fed into the combustion chamber 3, and the switch valve 27 is held at the bypass closed position.

[0164] On the other hand, when it is determined at step 816 that the W_n becomes larger than W_{no} , the processing routine goes to step 817, at which the NO_x releasing flag is set, and then the processing cycle is completed. In the next processing cycle, it is determined at step 814 that the NO_x releasing flag has been set, and therefore the processing routine goes to step 818, at which the correction coefficient K_t is made KK_1 . The value of this KK_1 is a value of about 1.1 to 1.2 with which the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes about 12.0 to 13.5. When K_t is made KK_1 , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich. Subsequently, at step 819, it is determined whether or not the NO_x amount W_n has become smaller than the lower limit value MIN (Fig. 31), and when $W_n \geq MIN$, the processing cycle is completed. Contrary to this, when W_n becomes smaller than MIN , the processing routine goes to step 820, at which the NO_x releasing flag is set. When the NO_x releasing flag is reset, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is switched from rich to lean. Accordingly, during a period from when W_n becomes larger than W_{no} to when W_n becomes smaller than MIN , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, and during this time, the NO_x is released from the NO_x absorbent 19.

[0165] On the other hand, when it is decided at step

815 that the SO_x amount W_s has become larger than the maximum allowable value W_{so} , the processing routine goes to step 821, at which it is determined whether or not the temperature T of exhaust gas flowing into the SO_x absorbent 18 is higher than the set value T_0 (Fig. 26A).

When $T \leq T_0$, the processing cycle is completed. Contrary to this, when $T > T_0$, the processing routine goes to step 822, at which the SO_x and NO_x releasing flag is set and then the processing cycle is completed.

[0166] In the next processing cycle, it is decided at step 823 that the SO_x and NO_x releasing flag has been set, and therefore the processing routine goes to step 823, at which it is determined whether or not the SO_x amount W_s has become smaller than the lower limit value MIN . When $W_s > MIN$, the processing routine goes to step 824, at which the correction coefficient K_t is made KK_2 . The value of this KK_2 is a value of about 1.1 to 1.2 with which the air-fuel ratio of the air-fuel mixture fed into the engine combustion chamber 3 becomes about 12.0 to 13.5. It is also possible to make the value of this KK_2 different from the value of KK_1 , or make this the same value as the value of KK_1 . When the correction coefficient K_t is made KK_2 , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich.

Subsequently, at step 825, the switch valve 27 is switched to the bypass opening position. Subsequently, the processing cycle is completed. Accordingly, if $T > T_0$ when W_s becomes larger than W_{so} , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich from when W_s becomes larger than W_{so} to when W_s becomes smaller than MIN and, at the same time, the switch valve 27 is held at the bypass closed position. Thus, during this term, the SO_x is released from the SO_x absorbent 18, and the released SO_x is fed into the bypass passage 24.

[0167] On the other hand, when it is determined at step 823 that W_s becomes smaller than MIN , the processing routine goes to step 826, at which the correction coefficient K_t is made KK_1 , and then the processing routine goes to step 827, at which the switch valve 27 is switched to the bypass closed position. Subsequently, at step 828, it is determined whether or not the NO_x amount W_n becomes smaller than the lower limit value MIN , and when $W_n \geq MIN$, the processing cycle is completed. Contrary to this, when W_n becomes smaller than MIN , the processing routine goes to step 829, at which the SO_x and NO_x releasing flag is reset, and then the processing cycle is completed. Accordingly, when W_s becomes smaller than MIN , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich ($K_t = KK_1$) until when W_n becomes smaller than MIN , and the switch valve 27 is held at the bypass closed position. Accordingly, this means that NO_x is released from the NO_x absorbent 19 during this time.

[0168] On the other hand, when it is determined at step 809 that $K \geq 1.0$, that is, when the target air-fuel ratio of the air-fuel mixture which should be fed into the combustion chamber 3 becomes the stoichiometric air-

fuel ratio or rich, the processing routine goes to step 830, at which the NO_x releasing flag is reset, and then the processing routine goes to step 831, at which the SO_x and NO_x releasing flag is reset. Subsequently, at step 832, the switch valve control shown in Fig. 37D is carried out. In this switch valve control, as shown in Fig. 37D, first of all, at step 833, it is determined whether or not the SO_x processing flag has been set. When the SO_x processing flag has not been set, the processing routine goes to step 834, at which it is determined whether or not the SO_x amount W_s is larger than the set up value W_k ($\text{MIN} < W_k < W_{so}$). When $W_s \leq W_k$, the processing routine goes to step 836, at which the switch valve 27 is made the bypass closed position. When $W_s \leq W_k$, even if the SO_x is released from the SO_x absorbent 18, the amount of the released SO_x is small, and therefore the switch valve 27 is made the bypass closed position.

[0169] Contrary to this, when $W_s > W_k$, the processing routine goes to step 835, at which it is determined whether or not the temperature T of exhaust gas flowing into the SO_x absorbent 18 is higher than the set value T_0 (Fig. 26A). When $T \leq T_0$, the processing routine goes to step 836. Namely, when $T \leq T_0$, almost no SO_x is released from the SO_x absorbent 18, and therefore switch valve 27 is made the bypass closed position. Note that, the NO_x is released from the NO_x absorbent 19 when the switch valve 27 is held at the bypass closed position.

[0170] On the other hand, when it is decided at step 835 that $T > T_0$, the processing routine goes to step 837, at which the SO_x processing flag is set. When the SO_x processing flag is set, the processing routine goes from step 833 to step 838, at which the switch valve 27 is switched to the bypass opening position. Namely, when $W_s > W_k$ and $T > T_0$, a certain amount of the SO_x is released from the SO_x absorbent 18, and therefore the switch valve 27 is made the bypass opening position so as to feed the released SO_x into the bypass passage 24. Subsequently, at step 839, it is determined whether or not the amount W_s of SO_x becomes smaller than the lower limit value MIN . When W_s becomes smaller than MIN , the processing routine goes to step 840, at which the SO_x processing flag is reset. When the SO_x processing flag is reset, in the next processing cycle, the processing routine goes from step 833 to step 834, since it is determined that W_s is equal to or smaller than W_k at this time, and therefore the processing routine goes to step 836, at which the switch valve 27 is switched to the bypass closed position.

[0171] On the other hand, where the SO_x flag has been set when the operation state is changed from the state where $K \geq 1.0$ to the state where $K < 1.0$, the processing routine goes from step 810 to step 811, at which the SO_x processing flag is reset. Subsequently, at step 812, the switch valve 27 is switched to the bypass closed position.

[0172] Figure 38 shows the calculation routine of the fuel injection time TAU , which routine is exactly the same as the routine shown in Fig. 36.

[0173] Namely, referring to Fig. 38, first of all, at step 850, the correction coefficient K determined in accordance with the engine operation state shown in Fig. 25 is calculated. Subsequently, at step 851, the basic fuel injection time TP is calculated from the map shown in Fig. 2. Subsequently, at step 852, it is determined whether or not the NO_x releasing flag has been set, and when the NO_x releasing flag has not been set, the processing routine goes to step 853, at which it is determined whether or not the SO_x and NO_x releasing flag has been set. When the SO_x and NO_x releasing flag has not been set, the processing routine goes to step 854, at which the correction coefficient K is made K_t , and then at step 855, the fuel injection time TAU ($= \text{TP} \cdot K_t$) is calculated by multiplying the basic fuel injection time TP by K_t . Accordingly, when the NO_x releasing flag and the SO_x and NO_x releasing flag have not been set, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes the air-fuel ratio determined by the correction coefficient K_t .

[0174] Contrary to this, when the NO_x releasing flag is set, the processing routine jumps to step 855, and when the SO_x and NO_x releasing flag is set, the processing routine goes to step 855. When the NO_x releasing flag is set, in the routine shown in Figs. 37A to 37D, K_t is made equal to KK_1 ($KK_1 > 1.0$), and therefore the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, while when the SO_x and NO_x releasing flag is set, in the routine shown in Figs. 37A to 37D, K_t is made equal to KK_2 ($KK_2 > 1.0$), and then K_t is made equal to KK_1 ($KK_1 > 1.0$), and therefore the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich.

[0175] Figures 39A to 39E show the flag switch valve control routine for performing the NO_x and SO_x releasing control shown in Fig. 29 when the exhaust gas temperature T is lower than the set up temperature T_t , while performing the NO_x and SO_x releasing control shown in Fig. 30 when the exhaust gas temperature T becomes higher than the set temperature T_t , which routine is executed by interruption at every predetermined time interval. Note that, in this embodiment, the flow chart part shown in Fig. 39A, Fig. 39B, and Fig. 39E is substantially the same as the flow chart part shown in Fig. 32A, Fig. 32B, and Fig. 32D, and the part which is basically different from them is only a flow chart part shown in Fig. 39C and Fig. 39D.

[0176] Namely, referring to Figs. 39A to 39E, first of all, at step 900, it is determined whether or not the correction coefficient K_t with respect to the basic fuel injection time TP is smaller than 1.0. When $K_t < 1.0$, that is, when the lean air-fuel mixture is fed into the combustion chamber 3, the processing routine goes to step 901, at which the NO_x amount W_n ($= W_s + K_1 \cdot N \cdot PM$) is calculated, and then the processing routine goes to step 902, at which the SO_x amount W_s ($= W_s + K_2 \cdot N \cdot PM$) is calculated. Here, N indicates the engine rotational speed, P indicates the absolute pressure in the surge

tank 10, and K_1 and K_2 indicate constants ($K_1 > K_2$). Then, the processing routine goes to step 909.

[0177] On the other hand, when it is determined at step 900 that $Kt \geq 1.0$, that is, when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is the stoichiometric air-fuel ratio or rich, the processing routine goes to step 903, at which the NO_x amount Wn ($= Wn - Wn \cdot f(T) \cdot g(Kt)$) is calculated, and then the processing routine goes to step 904, at which the SO_x amount Ws ($= Ws - Ws \cdot g(T) \cdot g(Kt)$) is calculated. Here, $f(T)$ and $g(T)$ indicate the NO_x releasing rate and SO_x releasing rate shown in Fig. 26A, respectively, and $f(Kt)$ and $g(Kt)$ indicate the NO_x releasing rate and SO_x releasing rate shown in Fig. 26B, respectively.

[0178] When the NO_x amount Wn is calculated at step 903, and the SO_x amount Ws is calculated at step 904, the processing routine goes to step 905, at which it is determined whether or not the NO_x amount Wn has become negative. When $Wn < 0$, the processing routine goes to step 906, at which Wn is made zero, and then, the processing routine goes to step 907. At step 907, it is determined whether or not the SO_x amount Ws becomes negative. When $Ws < 0$, the processing routine goes to step 908, at which Ws is made zero, and then the processing routine goes to step 909.

[0179] At step 909, it is determined whether or not the correction coefficient K determined according to the engine operation state shown in Fig. 25 is smaller than 1.0. When $K < 1.0$, that is, when the target air-fuel ratio determined according to the operation state of the engine is lean, the processing routine goes to step 910, at which it is determined whether or not the SO_x processing has been set. When the SO_x processing flag has not been set, the routine jumps to step 913, at which it is determined whether or not the SO_x and NO_x releasing flag has been set. When the SO_x and NO_x releasing flag has not been set, the processing routine goes to step 914, at which it is determined whether or not the NO_x releasing flag has been set. When the NO_x releasing flag has not been set, the processing routine goes to step 915.

[0180] At step 915, it is determined whether or not the SO_x amount Ws has become larger than the maximum allowable value Wso (Fig. 31). When $Ws \leq Wso$, the processing routine goes to step 916, at which it is determined whether or not the NO_x amount Wn has become larger than the maximum allowable value Wno . When $Wn \leq Wno$, the processing cycle is completed. At this time, the lean air-fuel mixture is fed into the combustion chamber 3, and the switch valve 27 is held at the bypass closed position.

[0181] On the other hand, when it is determined at step 916 that the Wn becomes larger than Wno , the processing routine goes to step 917, at which the NO_x releasing flag is set, and then the processing cycle is completed. In the next processing cycle, it is determined at step 914 that the NO_x releasing flag has been set, and therefore the processing routine goes to step 918, at which the correction coefficient Kt is made $KK1$. The

value of this $KK1$ is a value of about 1.1 to 1.2 with which the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes about 12.0 to 13.5. When Kt is made $KK1$, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich. Subsequently, at step 919, it is determined whether or not the NO_x amount Wn has become smaller than the lower limit value MIN (Fig. 31), and when $Wn \geq MIN$, the processing cycle is completed. Contrary to this, when Wn becomes smaller than MIN , the processing routine goes to step 920, at which the NO_x releasing flag is set. When the NO_x releasing flag is reset, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is switched from rich to lean. Accordingly, during a period from when Wn becomes larger than Wno to when Wn becomes smaller than MIN , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, and during this time, the NO_x is released from the NO_x absorbent 19.

[0182] On the other hand, when it is decided at step 915 that the SO_x amount Ws has become larger than the maximum allowable value Wso , the processing routine goes to step 921, at which it is determined whether or not the temperature T of exhaust gas flowing into the SO_x absorbent 18 is higher than the set value To (Fig. 26A). When $T \leq To$, the processing cycle is completed. Contrary to this, when $T > To$, the processing routine goes to step 922, at which the SO_x and NO_x releasing flag is set and then the processing cycle is completed.

[0183] In the next processing cycle, it is decided at step 913 that the SO_x and NO_x releasing flag has been set, and therefore the processing routine goes to step 923, at which it is determined whether or not the exhaust gas temperature T is higher than the set up temperature Tt ($Tt > To$). When $T \leq Tt$, the processing routine goes to step 924, at which it is determined whether or not the NO_x amount Wn becomes smaller than the lower limit value MIN . When $Wn > MIN$, the processing routine goes to step 925, at which the correction coefficient Kt is made $KK1$, and then the processing cycle is completed. Accordingly, when $To < T \leq Tt$, if Ws becomes larger than Wso , the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich ($Kt = KK1$) until Wn becomes smaller than MIN , and the switch valve 27 is held the bypass closed position. Accordingly, during this time, the NO_x will be released from the NO_x absorbent 19.

[0184] On the other hand, when it is decided at step 924 that Wn becomes smaller than MIN , the processing routine goes to step 926, at which the correction coefficient Kt is made $KK2$. The value of this $KK2$ is a value of about 1.1 to 1.2 with which the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes about 12.0 to 13.5. It is also possible to make the value of this $KK2$ different from the value of $KK1$, or make this the same value as the value of $KK1$. When the correction coefficient Kt is made $KK2$, the air-fuel ratio of the air-fuel mixture fed into the combustion

chamber 3 is made rich. Subsequently, at step 927, the switch valve 27 is switched to the bypass opening position. Thus, the exhaust gas flowing out of the SO_x absorbent 18 is fed into the bypass passage 24.

[0185] Subsequently, at step 928, it is determined whether or not the SO_x amount Ws becomes smaller than the lower limit value MIN, and when Ws ≥ MIN, the processing cycle is completed. Contrary to this, when Ws becomes smaller than MIN, the processing routine goes to step 929, at which the switch valve 27 is switched to the bypass closed position, and then the processing routine goes to step 930, at which the SO_x and NO_x releasing flag is reset. When the SO_x and NO_x releasing flag is reset, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is switched from rich to lean. Accordingly, if Tt ≥ T > To when Ws becomes larger than Wso, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich (K = KK2) from when Wn becomes smaller than MIN to when Ws becomes smaller than MIN and, at the same time, the switch valve 27 is made the bypass opening position. Thus, during this time, the SO_x is released from the SO_x absorbent 18, and the released SO_x is fed into the bypass passage 24.

[0186] On the other hand, when it is determined at step 923 that T > Tt, the processing routine goes to step 931, at which it is determined whether or not the SO_x amount Ws has become smaller than the lower limit value MIN. When Ws > MIN, the processing routine goes to step 932, at which the correction coefficient Kt is made KK2. When the correction coefficient Kt is made KK2, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich. Subsequently, at step 933, the switch valve 27 is switched to the bypass opening position. Subsequently, the processing cycle is completed. Accordingly, if T > Tt when Ws becomes larger than Wso, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich from when Ws becomes larger than Wso to when Ws becomes smaller than MIN and, at the same time, the switch valve 27 is held at the bypass closed position. Thus, during this term, the SO_x is released from the SO_x absorbent 18, and the released SO_x is fed into the bypass passage 24.

[0187] On the other hand, when it is determined at step 931 that Ws becomes smaller than MIN, the processing routine goes to step 934, at which the correction coefficient Kt is made KK1, and then the processing routine goes to step 935, at which the switch valve 27 is switched to the bypass closed position. Subsequently, at step 936, it is determined whether or not the NO_x amount Wn becomes smaller than the lower limit value MIN, and when Wn ≥ MIN, the processing cycle is completed. Contrary to this, when Wn becomes smaller than MIN, the processing routine goes to step 937, at which the SO_x and NO_x releasing flag is reset, and then the processing cycle is completed. Accordingly, when Ws becomes smaller than MIN, the air-fuel ratio

of the air-fuel mixture fed into the combustion chamber 3 is made rich (Kt = KK1) until when Wn becomes smaller than MIN, and the switch valve 27 is held at the bypass closed position. Accordingly, this means that NO_x is released from the NO_x absorbent 19 during this time.

[0188] On the other hand, when it is determined at step 909 that K ≥ 1.0, that is, when the target air-fuel ratio of the air-fuel mixture which should be fed into the combustion chamber 3 becomes the stoichiometric air-fuel ratio or rich, the processing routine goes to step 938, at which the NO_x releasing flag is reset, and then the processing routine goes to step 939, at which the SO_x and NO_x releasing flag is reset. Subsequently, at step 940, the switch valve control shown in Fig. 39E is carried out. In this switch valve control, as shown in Fig. 39E, first of all, at step 941, it is determined whether or not the SO_x processing flag has been set. When the SO_x processing flag has not been set, the processing routine goes to step 942, at which it is determined whether or not the SO_x amount Ws is larger than the set value Wk (MIN < Wk < Wso). When Ws ≤ Wk, the processing routine goes to step 944, at which the switch valve 27 is made the bypass closed position. When Ws ≤ Wk, even if the SO_x is released from the SO_x absorbent 18, the amount of the released SO_x is small, and therefore the switch valve 27 is made the bypass closed position.

[0189] Contrary to this, when Ws > Wk, the processing routine goes to step 943, at which it is determined whether or not the temperature T of exhaust gas flowing into the SO_x absorbent 18 is higher than the set value To (Fig. 26A). When T ≤ To, the processing routine goes to step 944. Namely, when T ≤ To, almost no SO_x is released from the SO_x absorbent 18, and therefore switch valve 27 is made the bypass closed position. Note that, the NO_x is released from the NO_x absorbent 19 when the switch valve 27 is held at the bypass closed position.

[0190] On the other hand, when it is decided at step 943 that T > To, the processing routine goes to step 945, at which the SO_x processing flag is set. When the SO_x processing flag is set, the processing routine goes from step 941 to step 946, at which the switch valve 27 is switched to the bypass opening position. Namely, when Ws > Wk and T > To, a certain amount of the SO_x is released from the SO_x absorbent 18, and therefore the

switch valve 27 is made the bypass opening position so as to feed the released SO_x into the bypass passage 24. Subsequently, at step 947, it is determined whether or not the amount Ws of SO_x becomes smaller than the lower limit value MIN. When Ws becomes smaller than MIN, the processing routine goes to step 948, at which the SO_x processing flag is reset. When the SO_x processing flag is reset, in the next processing cycle, the processing routine goes from step 941 to step 942, since it is determined that Ws is equal to or smaller than Wk at this time, and therefore the processing routine goes to step 944, at which the switch valve 27 is switched to the bypass closed position.

[0191] On the other hand, where the SO_x flag has

been set when the operation state is changed from the state where $K \geq 1.0$ to the state where $K < 1.0$, the processing routine goes from step 910 to step 911, at which the SO_x processing flag is reset. Subsequently, at step 912, the switch valve 27 is switched to the bypass closed position.

[0192] Figure 40 shows the calculation routine of the fuel injection time TAU , which routine is exactly the same as the routine shown in Fig. 36.

[0193] Namely, referring to Fig. 40, first of all, at step 950, the correction coefficient K determined in accordance with the engine operation state shown in Fig. 25 is calculated. Subsequently, at step 951, the basic fuel injection time TP is calculated from the map shown in Fig. 2. Subsequently, at step 952, it is determined whether or not the NO_x releasing flag has been set, and when the NO_x releasing flag has not been set, the processing routine goes to step 953, at which it is determined whether or not the SO_x and NO_x releasing flag has been set. When the SO_x and NO_x releasing flag has not been set, the processing routine goes to step 954, at which the correction coefficient K is made K_t , and then at step 955, the fuel injection time TAU ($= \text{TP} \cdot K_t$) is calculated by multiplying the basic fuel injection time TP by K_t . Accordingly, when the NO_x releasing flag and the SO_x and NO_x releasing flag have not been set, the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes the air-fuel ratio determined by the correction coefficient K .

[0194] Contrary to this, when the NO_x releasing flag is set, the processing routine jumps to step 955, and when the SO_x and NO_x releasing flag is set, the processing routine goes to step 955. When the NO_x releasing flag is set, in the routine shown in Figs. 39A to 39E, K_t is made equal to KK1 ($\text{KK1} > 1.0$), and therefore the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich, while when the SO_x and NO_x releasing flag is set, in the routine shown in Figs. 39A to 39E, K_t is made equal to KK1 ($\text{KK1} > 1.0$) or K_t is made equal to KK2 ($\text{KK2} > 1.0$), and therefore the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich.

Claims

1. A purification process for purifying exhaust gas of an internal combustion engine provided with:

an exhaust passage;
an NO_x absorbent (19) which is arranged in said exhaust passage, absorbing the NO_x when the air-fuel ratio of an inflowing exhaust gas is lean and releasing the absorbed NO_x when an oxygen concentration in the inflowing exhaust gas is lowered;
an SO_x absorbent (18) which is arranged in said exhaust passage on the upstream side of

5

said NO_x absorbent (19), absorbing the SO_x when the air-fuel ratio of the inflowing exhaust gas is lean and releasing the absorbed SO_x when the air-fuel ratio of the inflowing exhaust gas is made rich; and
an air-fuel ratio control means which controls the air-fuel ratio of the exhaust gas,

characterized in that

the air-fuel ratio control means usually maintains the air-fuel ratio of the exhaust gas flowing into said SO_x absorbent (18) lean, and makes the air-fuel ratio of the exhaust gas flowing into said SO_x absorbent (18) rich when the SO_x should be released from said SO_x absorbent (18).

2. A purification process according to claim 1, wherein all the exhaust gas discharged from the engine flows into the SO_x absorbent and the NO_x absorbent.
3. A purification process according to claim 1, wherein said air-fuel ratio control means controls the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent by controlling the air-fuel ratio of the air-fuel mixture burned in the engine; the SO_x contained in the exhaust gas is absorbed into the SO_x absorbent when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent is maintained lean by maintaining the air-fuel ratio of the air-fuel mixture burned in the engine lean, while the NO_x contained in the exhaust gas is absorbed into the NO_x absorbent.
4. A purification process according to claim 3, wherein said air-fuel ratio control means releases the SO_x from the SO_x absorbent and, at the same time, makes the air-fuel ratio of the air-fuel mixture burned in the engine rich when the NO_x should be released from the NO_x absorbent.
5. A purification process according to claim 4, wherein when said air-fuel ratio control means should release the SO_x from the SO_x absorbent and, at the same time, release the NO_x from the NO_x absorbent, it first makes the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent and the NO_x absorbent first degree of richness determined in advance, and then maintains the same at a rich state by a second degree of richness smaller than this first degree of richness.
6. A purification process according to claim 5, wherein said air-fuel ratio control means controls said first degree of richness and second degree of richness in accordance with a temperature representative of the temperature of the SO_x absorbent.

7. A purification process according to claim 6, wherein as temperature representing the temperature of the SO_x absorbent the temperature of the exhaust gas flowing into the SO_x absorbent is taken.
8. A purification process according to claim 6, wherein said air-fuel ratio control means makes said first degree of richness larger as the temperature representing the temperature of the SO_x absorbent becomes higher.
9. A purification process according to claim 8, wherein said air-fuel ratio control means makes the time for which the air-fuel ratio of the exhaust gas is maintained at said first degree of richness shorter as the temperature representing the temperature of the SO_x absorbent becomes higher.
10. A purification process according to claim 6, wherein said air-fuel ratio control means makes said second degree of richness larger as the temperature representing the temperature of the SO_x absorbent becomes higher.
11. A purification process according to claim 10, wherein said air-fuel ratio control means makes the time for which the air-fuel ratio of the exhaust gas is maintained at said second degree of richness shorter as the temperature representing the temperature of the SO_x absorbent becomes higher.
12. A purification process according to claim 4, wherein said air-fuel ratio control means makes the air-fuel ratio of the air-fuel mixture rich so as to release the NO_x from the NO_x absorbent with a time interval shorter than the time interval at which it makes the air-fuel ratio of the air-fuel mixture rich so as to release the SO_x from the SO_x absorbent and release the NO_x from the NO_x absorbent.
13. A purification process according to claim 12, wherein in said air-fuel ratio control means first of all makes the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent and the NO_x absorbent the predetermined degree of richness when the NO_x should be released from the NO_x absorbent, and then maintains the same at the stoichiometric air-fuel ratio.
14. A purification process according to claim 13, wherein in said air-fuel ratio control means controls said degree of richness in accordance with a temperature representative of the temperature of the NO_x absorbent.
15. A purification process according to claim 14, wherein as temperature representing the temperature of the NO_x absorbent the temperature of the exhaust
- gas flowing into the NO_x absorbent is taken.
- 5 16. A purification according to claim 14, wherein said air-fuel ratio control means makes said degree of richness larger as the temperature representing the temperature of the NO_x absorbent becomes higher.
- 10 17. A purification process according to claim 16, wherein in said air-fuel ratio control means makes the time for which the air-fuel ratio of the exhaust gas is maintained at said degree of richness shorter as the temperature representing the temperature of the NO_x absorbent becomes higher.
- 15 18. A purification process according to claim 13, wherein in said air-fuel ratio control means makes the time for which the air-fuel ratio of the exhaust gas is maintained at the stoichiometric air-fuel ratio shorter as the temperature representing the temperature of the SO_x absorbent becomes higher.
- 20 19. A purification process according to claim 1, wherein the NO_x absorbent is bypassed by a bypass passage which is branched from the exhaust passage positioned between the SO_x absorbent and the NO_x absorbent, the exhaust gas is selectively introduced to either of the NO_x absorbent or the bypass passage, wherein a switch valve is held by a valve control means at a position at which the exhaust gas flows into the NO_x absorbent when the NO_x should be released from the NO_x absorbent and is switched to a position at which the exhaust gas flowing into the bypass passage when the SO_x should be released from the SO_x absorbent, and said air-fuel ratio control means lowers the oxygen concentration in the exhaust gas flowing into the NO_x absorbent when the NO_x should be released from the NO_x absorbent and makes the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent rich when the SO_x should be released from the SO_x absorbent.
- 25 20. A purification process according to claim 19, wherein in said valve control means and said air-fuel ratio control means hold the switch valve at a position at which the exhaust gas flows into the NO_x absorbent when the SO_x should be released from the SO_x absorbent and, at the same time, make the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent rich, and thereafter switches the switch valve to a position at which the exhaust gas flows into the bypass passage and, at the same time, continuously maintains the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent rich.
- 30 21. A purification process according to claim 20, wherein in said valve control means and said air-fuel ratio control means hold the switch valve at a position at
- 35 40 45 50 55

- which the exhaust gas flows into the bypass passage when the SO_x should be released from the SO_x absorbent and, at the same time, make the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent rich, and thereafter switches the switch valve to the position at which the exhaust gas flows into the NO_x absorbent and, at the same time, continuously maintains the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent rich.
22. A purification process according to claim 19, wherein said valve control means and said air-fuel ratio control means hold the switch valve at a position at which the exhaust gas flows into the NO_x absorbent, if the temperature representing the temperature of the SO_x absorbent is lower than the predetermined set up temperature when the SO_x should be released from the SO_x and, at the same time, make the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent rich, and thereafter switch the switch valve to a position at which the exhaust gas flows into the bypass passage and, at the same time, continuously maintain the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent rich; said valve control means and said air-fuel ratio control means switch the switch valve to a position at which the exhaust gas flows into the bypass passage, if the temperature representing the temperature of the SO_x absorbent is higher than the predetermined set temperature when the SO_x should be released from the SO_x and, at the same time, make the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent rich, and thereafter hold the switch valve at a position at which the exhaust gas flows into the NO_x absorbent and, at the same time, continuously maintain the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent rich.
23. A purification process according to claim 1, wherein the oxygen concentration in the exhaust gas flowing into the NO_x absorbent is lowered by a NO_x releasing control means exactly for a second set period determined in advance so as to release the NO_x from the NO_x absorbent when the period for which the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent is made lean and the NO_x is absorbed into the NO_x absorbent exceeds the predetermined first set period.
24. A purification process according to claim 23, wherein said NO_x releasing control means provides a NO_x amount estimation means which estimates the amount of NO_x absorbed in the NO_x absorbent, and said NO_x releasing control means decides that said first set period has elapsed when the NO_x amount estimated by said NO_x amount estimation means exceeds a predetermined maximum value.
- 5 25. A purification process according to claim 24, wherein said NO_x amount estimation means decides that the amount of NO_x absorbed in the NO_x absorbent exceeds said maximum value when the cumulative value of the engine rotational speed exceeds a predetermined set value.
- 10 26. A purification process according to claim 25, wherein said NO_x amount estimation means estimates the amount of NO_x absorbed into the NO_x absorbent from the amount of NO_x contained in the exhaust gas when the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent is lean, estimates the amount of NO_x released from the NO_x absorbent based on the degree of richness of said exhaust gas when the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent is rich and based on the temperature representing the temperature of the NO_x absorbent, and estimates the amount of NO_x continuously absorbed into the NO_x absorbent from this estimated NO_x release.
- 15 27. A purification process according to claim 26, wherein said NO_x releasing control means decides that said second set period has elapsed when the NO_x amount estimated by said NO_x estimation means becomes smaller than a predetermined minimum value.
- 20 28. A purification process according to claim 1, wherein the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent is made rich by a SO_x releasing control means exactly for a second set period determined in advance so as to release the SO_x from the SO_x absorbent when the period for which the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent is made lean and the SO_x is absorbed into the SO_x absorbent exceeds the predetermined first set period.
- 25 29. A purification process according to claim 28, wherein the amount of NO_x absorbed in the SO_x absorbent is estimated by a SO_x amount estimation means provided by said SO_x releasing control means, and said SO_x releasing control means decides that said first set period has elapsed when the SO_x amount estimated by said SO_x amount estimation means exceeds a predetermined maximum value and decides that said second period has elapsed when the SO_x amount estimated by said SO_x amount estimation means becomes smaller than a predetermined maximum value.
- 30 30. A purification process according to claim 29, wherein said SO_x amount estimation means estimates the amount of SO_x absorbed into the SO_x absorbent from the amount of SO_x contained in the exhaust gas when the air-fuel ratio of the exhaust gas flow-
- 35
- 40
- 45
- 50
- 55

ing into the SO_x absorbent is lean, estimates the amount of SO_x released from the SO_x absorbent based on the degree of richness of said exhaust gas when the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent is rich and based on the temperature representing the temperature of the SO_x absorbent, and estimates the amount of SO_x continuously absorbed into the SO_x absorbent from this released SO_x amount.

10

31. A purification process according to claim 1, wherein said air-fuel ratio control means controls the air-fuel ratio of the exhaust gas in the exhaust passage and makes the air-fuel ratio of the exhaust gas flowing into the SO_x absorbent rich when the SO_x should be released from the SO_x absorbent. 15
32. A purification process according to claim 31, wherein said air-fuel ratio control means feeds a reduction agent into the exhaust passage when the SO_x should be released from the SO_x absorbent. 20
33. A purification process according to claim 32, wherein as reduction agent an agent is chosen composed of at least one member selected from gasoline, iso-octane, hexane, heptane, butane, propane, light oil, and lamp oil. 25
34. An exhaust purification device for conducting the process according to claim 1, wherein the NO_x absorbent contains at least one member selected from alkali metals consisting of potassium, sodium, lithium, cesium and alkali earths consisting of barium and calcium, and rare earths consisting of lanthanum, yttrium and platinum. 30
35. An exhaust purification device for conducting the process according to claim 1, wherein the SO_x absorbent contains at least one member selected from copper, iron, manganese, nickel, sodium, tin, titanium, lithium and titania. 35
36. An exhaust purification device for conducting the process according to claim 1, wherein the SO_x absorbent contains the platinum. 40
37. An exhaust purification device for conducting the process according to claim 2, wherein the SO_x absorbent and the NO_x absorbent are arranged in one casing. 45
38. An exhaust purification device for conducting the process according to claim 19, wherein provision is made of a bypass passage which is branched from the exhaust passage position between the SO_x absorbent and the NO_x absorbent; a switch valve is arranged at the branched portion of the bypass passage from the exhaust passage and a valve control

means is provided which forms the switching control of said switch valve.

5 Patentansprüche

1. Reinigungsverfahren zum Reinigen von Abgas einer Brennkraftmaschine, die mit folgendem versehen ist:

einem Abgaskanal;
einem NO_x Absorptionsmittel (19), das angeordnet ist in dem Abgaskanal, das die NO_x absorbiert, wenn das Luft-Kraftstoffverhältnis eines einströmenden Abgases mager ist, und die absorbierten NO_x freigibt, wenn eine Sauerstoffkonzentration in dem einströmenden Abgas gesenkt ist;
einem SO_x Absorptionsmittel (18), das angeordnet ist in dem Abgaskanal auf der stromaufwärtsigen Seite des NO_x Absorptionsmittels (19), das die SO_x absorbiert, wenn das Luft-Kraftstoffverhältnis des einströmenden Abgases mager ist, und die absorbierten SO_x freigibt, wenn das Luft-Kraftstoffverhältnis des einströmenden Abgases fett eingerichtet wird; und einer Luft-Kraftstoffverhältnisregeleinrichtung, die das Luft-Kraftstoffverhältnis des Abgases regelt,

dadurch gekennzeichnet, dass
die Luft-Kraftstoffverhältnisregeleinrichtung
gewöhnlich das Luft-Kraftstoffverhältnis des Abga-
ses, das in das SO_x Absorptionsmittel (18) ein-
strömt, mager hält, und das Luft-Kraftstoffverhältnis
des in das SO_x Absorptionsmittel (18) einströmenden
Abgases fett einrichtet, wenn die SO_x freige-
geben werden sollten aus dem SO_x Absorptions-
mittel (18).

2. Reinigungsverfahren nach Anspruch 1, wobei alle aus dem Motor abgegebenen Abgase in das SO_x Absorptionsmittel und das NO_x Absorptionsmittel einströmen.
3. Reinigungsverfahren nach Anspruch 1, wobei die Luft-Kraftstoffverhältnisregeleinrichtung das Luft-Kraftstoffverhältnis des in das SO_x Absorptionsmittel einströmenden Abgases regelt durch Regeln des Luft-Kraftstoffverhältnisses des in dem Motor verbrannten Luft-Kraftstoffgemisches; wobei die in dem Abgas enthaltenen SO_x absorbiert werden in dem SO_x Absorptionsmittel, wenn das Luft-Kraft-
stoffverhältnis des in das SO_x Absorptionsmittel einströmenden Abgases mager gehalten wird durch Magerhalten des Luft-Kraftstoffverhältnisses des in dem Motor verbrannten Luft-Kraftstoffgemis-
ches, während die in dem Abgas enthaltenen NO_x

- in dem NOx Absorptionsmittel absorbiert werden.
4. Reinigungsverfahren nach Anspruch 3, wobei die Luft-Kraftstoffverhältnisregeleinrichtung die SOx aus dem SOx Absorptionsmittel freigibt und gleichzeitig das Luft-Kraftstoffverhältnis des in dem Motor verbrannten Luft-Kraftstoffgemisches fest einrichtet, wenn die NOx aus dem NOx Absorptionsmittel freigegeben werden sollten.
 5. Reinigungsverfahren nach Anspruch 4, wobei, wenn die Luft-Kraftstoffverhältnisregeleinrichtung die SOx aus dem SOx Absorptionsmittel freigeben sollte und gleichzeitig die NOx aus dem NOx Absorptionsmittel freigeben sollte, sie zuerst das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel und das NOx Absorptionsmittel einströmenden Abgases auf einen ersten Grad der Fettheit einrichtet, der vorher ermittelt ist, und dann denselben bei einem fetten Zustand hält durch einen zweiten Grad der Fettheit, der kleiner ist als dieser erste Grad der Fettheit.
 6. Reinigungsverfahren nach Anspruch 5, wobei die Luft-Kraftstoffverhältnisregeleinrichtung den ersten Grad der Fettheit und den zweiten Grad der Fettheit regelt in Übereinstimmung mit einer Temperatur, die die Temperatur des SOx Absorptionsmittels repräsentiert.
 7. Reinigungsverfahren nach Anspruch 6, wobei die Temperatur des Abgases, das in das SOx Absorptionsmittel einströmt, genommen wird als eine Temperatur, die die Temperatur des SOx Absorptionsmittels repräsentiert.
 8. Reinigungsverfahren nach Anspruch 6, wobei die Luft-Kraftstoffverhältnisregeleinrichtung den ersten Grad der Fettheit größer einrichtet, wenn die Temperatur höher wird, die die Temperatur des SOx Absorptionsmittels repräsentiert.
 9. Reinigungsverfahren nach Anspruch 8, wobei die Luft-Kraftstoffverhältnisregeleinrichtung die Zeit kürzer einrichtet, für die das Luft-Kraftstoffverhältnis des Abgases bei dem ersten Grad der Fettheit gehalten wird, wenn die Temperatur höher wird, die die Temperatur des SOx Absorptionsmittels repräsentiert.
 10. Reinigungsverfahren nach Anspruch 6, wobei die Luft-Kraftstoffverhältnisregeleinrichtung den zweiten Grad der Fettheit größer einrichtet, wenn die Temperatur höher wird, die die Temperatur des SOx Absorptionsmittels repräsentiert.
 11. Reinigungsverfahren nach Anspruch 10, wobei die Luft-Kraftstoffverhältnisregeleinrichtung die Zeit
 - 5 kürzer einrichtet, für die das Luft-Kraftstoffverhältnis des Abgases bei dem zweiten Grad der Fettheit gehalten wird, wenn die Temperatur höher wird, die die Temperatur des SOx Absorptionsmittels repräsentiert.
 - 10 12. Reinigungsverfahren nach Anspruch 4, wobei die Luft-Kraftstoffverhältnisregeleinrichtung das Luft-Kraftstoffverhältnis des Luft-Kraftstoffgemisches fest einrichtet, um die NOx aus dem NOx Absorptionsmittel freizugeben mit einem Zeitintervall, das kürzer ist als das Zeitintervall, bei dem das Luft-Kraftstoffverhältnis des Luft-Kraftstoffgemisches fest eingerichtet wird, um die SOx aus dem SOx Absorptionsmittel freizugeben und die NOx aus dem NOx Absorptionsmittel freizugeben.
 - 15 13. Reinigungsverfahren nach Anspruch 12, wobei die Luft-Kraftstoffverhältnisregeleinrichtung zuerst das Luft-Kraftstoffverhältnis des Abgases, das in das SOx Absorptionsmittel und das NOx Absorptionsmittel einströmt, auf den vorgegebenen Grad der Fettheit einrichtet, wenn die NOx aus dem NOx Absorptionsmittel freigegeben werden sollten, und dann dasselbe bei dem stoichiometrischen Luft-Kraftstoffverhältnis hält.
 - 20 14. Reinigungsverfahren nach Anspruch 13, wobei die Luft-Kraftstoffverhältnisregeleinrichtung den Grad der Fettheit regelt in Übereinstimmung mit einer Temperatur, die die Temperatur des NOx Absorptionsmittels repräsentiert.
 - 25 15. Reinigungsverfahren nach Anspruch 14, wobei die Temperatur des in das NOx-Absorptionsmittel einströmenden Abgases genommen wird als die Temperatur, die die Temperatur des NOx Absorptionsmittels repräsentiert.
 - 30 16. Reinigungsverfahren nach Anspruch 14, wobei die Luft-Kraftstoffverhältnisregeleinrichtung den Grad der Fettheit größer einrichtet, wenn die Temperatur höher wird, die die Temperatur des NOx Absorptionsmittels repräsentiert.
 - 35 17. Reinigungsverfahren nach Anspruch 16, wobei die Luft-Kraftstoffverhältnisregeleinrichtung die Zeit kürzer einrichtet, für die das Luft-Kraftstoffverhältnis des Abgases bei dem Grad der Fettheit gehalten wird, wenn die Temperatur höher wird, die die Temperatur des NOx Absorptionsmittels repräsentiert.
 - 40 18. Reinigungsverfahren nach Anspruch 13, wobei die Luft-Kraftstoffverhältnisregeleinrichtung die Zeit kürzer einrichtet, für die das Luft-Kraftstoffverhältnis des Abgases bei dem stoichiometrischen Luft-Kraftstoffverhältnis gehalten wird, wenn die Temperatur höher wird, die die Temperatur des SOx Absorptionsmittels repräsentiert.
 - 45
 - 50
 - 55

- onsmittels repräsentiert.
19. Reinigungsverfahren nach Anspruch 1, wobei das NOx Absorptionsmittel mit einer Umgehungsleitung versehen ist durch einen Umgehungskanal, dervon dem Abgaskanal abzweigt an einer Position zwischen dem SOx Absorptionsmittel und dem NOx Absorptionsmittel, wobei das Abgas wahlweise eingeführt wird entweder in das NOx Absorptionsmittel oder den Umgehungskanal, wobei ein Umschaltventil gehalten ist durch eine Ventilregeleinrichtung bei einer Position, bei der das Abgas in das NOx Absorptionsmittel einströmt, wenn die NOx freigegeben werden sollten aus dem NOx Absorptionsmittel, und zu einer Position geschalten wird, bei der das Abgas in den Umgehungskanal einströmt, wenn die SOx aus dem SOx Absorptionsmittel freigegeben werden sollten, und die Luft-Kraftstoffverhältnisregeleinrichtung die Sauerstoffkonzentration in dem Abgas senkt, das in das NOx Absorptionsmittel einströmt, wenn die NOx freigegeben werden sollten aus dem NOx Absorptionsmittel, und das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases fett einrichtet, wenn die SOx aus dem SOx Absorptionsmittel freigegeben werden sollten.
20. Reinigungsverfahren nach Anspruch 19, wobei die Ventilregeleinrichtung und die Luft-Kraftstoffverhältnisregeleinrichtung das Schaltventil bei einer Position halten, bei der das Abgas in das NOx Absorptionsmittel einströmt, wenn die SOx aus dem SOx Absorptionsmittel freigegeben werden sollten, und gleichzeitig das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases fett einrichtet, und danach das Schaltventil zu einer Position schaltet, bei der das Abgas in den Umgehungskanal einströmt, und gleichzeitig das Luft-Kraftstoffverhältnis des Abgases kontinuierlich fett hält, das in das SOx Absorptionsmittel einströmt.
21. Reinigungsverfahren nach Anspruch 20, wobei die Ventilregeleinrichtung und die Luft-Kraftstoffverhältnisregeleinrichtung das Schaltventil bei einer Position halten, bei der das Abgas in den Umgehungskanal einströmt, wenn die SOx aus dem SOx Absorptionsmittel freigegeben werden sollten, und gleichzeitig das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases fett einrichtet, und danach das Schaltventil zu der Position schaltet, bei der das Abgas in das NOx Absorptionsmittel einströmt, und gleichzeitig das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases kontinuierlich fett hält.
22. Reinigungsverfahren nach Anspruch 19, wobei die Ventilregeleinrichtung und die Luft-Kraftstoffverhältnisregeleinrichtung das Schaltventil bei einer Position halten, bei der das Abgas in das NOx Absorptionsmittel einströmt, wenn die SOx aus dem SOx Absorptionsmittel freigegeben werden sollten, und gleichzeitig das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases fett einrichtet, und danach das Schaltventil zu einer Position schaltet, bei der das Abgas in den Umgehungskanal einströmt, und gleichzeitig das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases fett hält; wobei die Ventilregeleinrichtung und die Luft-Kraftstoffverhältnisregeleinrichtung das Schaltventil zu einer Position schalten, bei der das Abgas in den Umgehungskanal einströmt, wenn die Temperatur, die die Temperatur des SOx Absorptionsmittels repräsentiert, niedriger ist als die vorgegebene eingerichtete Temperatur, wenn die SOx freigegeben werden sollten aus dem SOx, und gleichzeitig das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases fett einrichtet und danach das Schaltventil zu einer Position schaltet, bei der das Abgas in den Umgehungskanal einströmt und gleichzeitig das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases kontinuierlich fett hält; wobei die Ventilregeleinrichtung und die Luft-Kraftstoffverhältnisregeleinrichtung das Schaltventil zu einer Position schalten, bei der das Abgas in den Umgehungskanal einströmt, wenn die Temperatur, die die Temperatur des SOx Absorptionsmittels repräsentiert, höher ist als die vorgegebene eingerichtete Temperatur, wenn die SOx freigegeben werden sollten aus dem SOx, und gleichzeitig das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases fett einrichtet und danach das Schaltventil bei einer Position hält, bei der das Abgas in das NOx Absorptionsmittel einströmt, und gleichzeitig kontinuierlich das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases fett hält.
23. Reinigungsverfahren nach Anspruch 1, wobei die Sauerstoffkonzentration in dem Abgas, das in das NOx Absorptionsmittel einströmt, gesenkt wird durch eine NOx Freigaberegeleinrichtung genau für eine zweite eingerichtete Periode, die im voraus ermittelt ist, um die NOx aus dem NOx Absorptionsmittel freizugeben, wenn die Periode, für die das Luftkraftstoffverhältnis des in das NOx Absorptionsmittel einströmenden Abgases mager eingerichtet ist, und die NOx absorbiert werden in dem NOx Absorptionsmittel, die vorgegebene erste eingerichtete Periode überschreitet.
24. Reinigungsverfahren nach Anspruch 23, wobei die NOx Freigaberegeleinrichtung eine NOx Mengenschätzteinrichtung schafft, die die Menge der in dem NOx Absorptionsmittel absorbierten NOx schätzt, und die NOx Freigaberegeleinrichtung entscheidet, dass die erste eingerichtete Periode verstrichen ist, wenn die durch die NOx Mengenschätzteinrichtung geschätzte NOx Menge einen vorgegebenen Maximalwert überschreitet.
25. Reinigungsverfahren nach Anspruch 24, wobei die NOx Mengenschätzteinrichtung entscheidet, dass die Menge der in dem NOx Absorptionsmittel absorbierten NOx den Maximalwert überschreitet, wenn der kumulative Wert der Motordrehzahl einen vorgegebenen eingerichteten Wert überschreitet.

26. Reinigungsverfahren nach Anspruch 25, wobei die NOx Mengenschätzteinrichtung die Menge der in dem NOx Absorptionsmittel absorbierten NOx schätzt aus der Menge der in dem Abgas enthaltenen NOx, wenn das Luft-Kraftstoffverhältnis des in das NOx Absorptionsmittel einströmenden Abgases mager ist, die Menge der aus dem NOx Absorptionsmittel freigegebenen NOx schätzt auf der Grundlage des Grads der Fettigkeit des Abgases, wenn das Luft-Kraftstoffverhältnis des in das NOx Absorptionsmittel einströmenden Abgases fett ist, und auf der Grundlage der Temperatur, die die Temperatur des NOx Absorptionsmittels repräsentiert, und die Menge der NOx schätzt, die kontinuierlich absorbiert werden in dem NOx Absorptionsmittel, aus dieser geschätzten NOx Freigabe.
- 5
27. Reinigungsverfahren nach Anspruch 26, wobei die NOx Freigaberegeleinrichtung entscheidet, dass die zweite eingerichtete Periode verstrichen ist, wenn die durch die NOx Schätzteinrichtung geschätzte NOx Menge kleiner wird als ein vorgegebener Minimalwert.
- 10
28. Reinigungsverfahren nach Anspruch 1, wobei das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases fett eingerichtet wird durch eine SOx Freigaberegeleinrichtung genau für eine zweite eingerichtete Periode, die im voraus ermittelt wird, um die SOx freizugeben aus dem SOx Absorptionsmittel, wenn die Periode, für die das Luftkraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases mager eingerichtet ist und die SOx absorbiert werden in dem SOx Absorptionsmittel, die vorgegebene erste eingerichtete Periode überschreitet.
- 15
29. Reinigungsverfahren nach Anspruch 28, wobei die Menge der in dem SOx Absorptionsmittel absorbierten NOx geschätzt wird durch eine SOx Mengenschätzteinrichtung, die durch die SOx Freigaberegeleinrichtung vorgesehen ist, und die SOx Freigaberegeleinrichtung entscheidet, dass die erste eingerichtete Periode verstrichen ist, wenn die durch die SOx Mengenschätzteinrichtung geschätzte SOx Menge einen vorgegebenen Maximalwert überschreitet, und entscheidet, dass die zweite Periode verstrichen ist, wenn die durch die SOx Mengenschätzteinrichtung geschätzte SOx Menge kleiner wird als ein vorgegebener Maximalwert.
- 30
30. Reinigungsverfahren nach Anspruch 29, wobei die SOx Mengenschätzteinrichtung die Menge der in dem SOx Absorptionsmittel absorbierten SOx schätzt aus der Menge der in dem Abgas enthaltenen SOx, wenn das Luft-Kraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases mager ist, die Menge der aus dem SOx Absorp-
- 35
- tionsmittel freigegebenen SOx schätzt auf der Grundlage des Grads der Fettigkeit des Abgases, wenn das Luft-Kraftstoffverhältnis des Abgases, das in das SOx Absorptionsmittel einströmt, fett ist, und auf der Grundlage der Temperatur, die die Temperatur des SOx Absorptionsmittels repräsentiert, und die Menge der SOx, die kontinuierlich absorbiert wird in dem SOx Absorptionsmittel, aus dieser freigegebenen SOx Menge schätzt.
- 40
31. Reinigungsverfahren nach Anspruch 1, wobei die Luft-Kraftstoffverhältnisregelteinrichtung das Luft-Kraftstoffverhältnis des Abgases in dem Abgaskanal regelt und das Luftkraftstoffverhältnis des in das SOx Absorptionsmittel einströmenden Abgases fett einrichtet, wenn die SOx aus dem SOx Absorptionsmittel freigegeben werden sollten.
- 45
32. Reinigungsverfahren nach Anspruch 31, wobei die Luft-Kraftstoffverhältnisregelteinrichtung ein Reduktionsmittel in den Abgaskanal einspeist, wenn die SOx aus dem SOx Absorptionsmittel freigegeben werden sollten.
- 50
33. Reinigungsverfahren nach Anspruch 32, wobei als ein Reduktionsmittel ein Mittel gewählt wird, das zusammengesetzt ist zumindest aus einem Element, das ausgewählt ist aus Benzin, Isooctan, Hexan, Heptan, Butan, Propan, Leichtöl oder Lampenöl.
- 55
34. Abgasreinigungsvorrichtung zum Durchführen des Verfahrens nach Anspruch 1, wobei das NOx Absorptionsmittel zumindest ein Element enthält, das ausgewählt ist aus Alkalimetallen, die aus Kalium, Natrium, Lithium, Cäsium bestehen, und Alkalierden, die aus Barium oder Kalzium bestehen, und seltenen Erden, die aus Lanthan, Yttrium oder Platin bestehen.
35. Abgasreinigungsvorrichtung zum Durchführen des Verfahrens nach Anspruch 1, wobei das SOx Absorptionsmittel zumindest ein Element enthält, das ausgewählt ist aus Kupfer, Eisen, Mangan, Nickel, Natrium, Zinn, Titan, Lithium oder Titanerde.
36. Abgasreinigungsvorrichtung zum Durchführen des Verfahrens nach Anspruch 1, wobei das SOx Absorptionsmittel Platin enthält.
37. Abgasreinigungsvorrichtung zum Durchführen des Verfahrens nach Anspruch 2, wobei das SOx Absorptionsmittel und das NOx Absorptionsmittel in einer Ummantelung angeordnet sind.
38. Abgasreinigungsvorrichtung zum Durchführen des Verfahrens nach Anspruch 19, wobei ein Umgehungskanal vorgesehen ist, der abzweigt von der Abgaskanalposition zwischen dem SOx Absorptionsmittel und dem NOx Absorptionsmittel.

onsmittel und dem NO_x Absorptionsmittel; wobei ein Schaltventil angeordnet ist bei dem Abzweigungsabschnitt des Umgehungskanals von dem Abgaskanal, und eine Ventileinrichtung vorgesehen ist, die die Schaltregelung des Schaltventils bildet.

Revendications

1. Procédé de purification destiné à purifier un gaz d'échappement d'un moteur à combustion interne muni de :

un passage d'échappement,
un adsorbant de NO_x (19) qui est agencé dans l'edit passage d'échappement, adsorbant le NO_x lorsque le rapport air-carburant d'un gaz d'échappement entrant est pauvre et libérant le NO_x adsorbé lorsqu'une concentration en oxygène dans le gaz d'échappement entrant est diminuée,
un adsorbant de SO_x (18) qui est agencé dans l'edit passage d'échappement du côté amont dudit adsorbant de NO_x (19), adsorbant le SO_x lorsque le rapport air-carburant du gaz d'échappement entrant est pauvre et libérant le SO_x adsorbé lorsque le rapport air-carburant du gaz d'échappement entrant est rendu riche, et
un moyen de commande de rapport air-carburant qui commande le rapport air-carburant du gaz d'échappement,

caractérisé en ce que

le moyen de commande de rapport air-carburant maintient habituellement pauvre le rapport air-carburant du gaz d'échappement circulant dans l'edit adsorbant de SO_x (18), et rend riche le rapport air-carburant du gaz d'échappement circulant dans l'edit adsorbant de SO_x (18) lorsque le SO_x devrait être libéré dudit adsorbant de SO_x (18).

2. Procédé de purification selon la revendication 1, dans lequel tout le gaz d'échappement rejeté du moteur circule dans l'adsorbant de SO_x et l'adsorbant de NO_x.

3. Procédé de purification selon la revendication 1, dans lequel ledit moyen de commande de rapport air-carburant commande le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x en commandant le rapport air-carburant du mélange air-carburant brûlé dans le moteur, le SO_x contenu dans le gaz d'échappement est adsorbé dans l'adsorbant de SO_x lorsque le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x est maintenu à l'état pauvre en

maintenant le rapport air-carburant du mélange air-carburant brûlé dans le moteur à l'état pauvre, alors que le NO_x contenu dans le gaz d'échappement est adsorbé dans l'adsorbant de NO_x.

4. Procédé de purification selon la revendication 3, dans lequel ledit moyen de commande de rapport air-carburant libère le SO_x de l'adsorbant de SO_x et, en même temps rend riche le rapport air-carburant du mélange air-carburant brûlé dans le moteur lorsque le NO_x devrait être libéré de l'adsorbant de NO_x.
5. Procédé de purification selon la revendication 4, dans lequel, lorsque ledit moyen de commande de rapport air-carburant devrait libérer le SO_x de l'adsorbant de SO_x et, en même temps, libérer le NO_x de l'adsorbant de NO_x, il amène tout d'abord le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x et l'adsorbant de NO_x à un premier degré de richesse déterminé à l'avance, et ensuite maintient celui-ci dans un état riche par un second degré de richesse plus petit que ce premier degré de richesse.
6. Procédé de purification selon la revendication 5, dans lequel ledit moyen de commande de rapport air-carburant commande ledits premier degré de richesse et second degré de richesse conformément à une température représentative de la température de l'adsorbant de SO_x.
7. Procédé de purification selon la revendication 6, dans lequel en tant que température représentant la température de l'adsorbant de SO_x, la température du gaz d'échappement circulant dans l'adsorbant de SO_x est prélevée.
8. Procédé de purification selon la revendication 6, dans lequel ledit moyen de commande de rapport air-carburant rend ledit premier degré de richesse plus grand lorsque la température représentant la température de l'adsorbant de SO_x devient plus élevée.
9. Procédé de purification selon la revendication 8, dans lequel ledit moyen de commande de rapport air-carburant rend le temps pendant lequel le rapport air-carburant du gaz d'échappement est maintenu audit premier degré de richesse, plus court lorsque la température représentant la température de l'adsorbant de SO_x devient plus élevée.
10. Procédé de purification selon la revendication 6, dans lequel ledit moyen de commande de rapport air-carburant rend ledit second degré de richesse plus grand lorsque la température représentant la température de l'adsorbant de SO_x devient plus élevée.

- vée.
11. Procédé de purification selon la revendication 10, dans lequel ledit moyen de commande de rapport air-carburant rend le temps pendant lequel le rapport air-carburant du gaz d'échappement est maintenu audit second degré de richesse, plus court lorsque la température représentant la température de l'adsorbant de SO_x devient plus élevée. 5
12. Procédé de purification selon la revendication 4, dans lequel ledit moyen de commande de rapport air-carburant rend riche le rapport air-carburant du mélange air-carburant de façon à libérer le NO_x de l'adsorbant de NO_x avec un intervalle de temps plus court que l'intervalle de temps pendant lequel il rend riche le rapport air-carburant du mélange air-carburant de façon à libérer le SO_x de l'adsorbant de SO_x et libérer le NO_x de l'adsorbant de NO_x . 10
13. Procédé de purification selon la revendication 12, dans lequel ledit moyen de commande de rapport air-carburant amène tout d'abord le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x et l'adsorbant de NO_x au degré de richesse prédéterminé lorsque le NO_x devrait être libéré de l'adsorbant de NO_x et maintient ensuite celui-ci au rapport air-carburant stoechiométrique. 15
14. Procédé de purification selon la revendication 13, dans lequel ledit moyen de commande de rapport air-carburant commande ledit degré de richesse conformément à une température représentative de la température de l'adsorbant de NO_x . 20
15. Procédé de purification selon la revendication 14, dans lequel en tant que température représentant la température de l'adsorbant de NO_x , la température du gaz d'échappement circulant dans l'adsorbant de NO_x est prélevée. 25
16. Procédé de purification selon la revendication 14, dans lequel ledit moyen de commande de rapport air-carburant rend ledit degré de richesse plus grand lorsque la température représentant la température de l'adsorbant de NO_x devient plus élevée. 30
17. Procédé de purification selon la revendication 16, dans lequel ledit moyen de commande de rapport air-carburant rend le temps pendant lequel le rapport air-carburant du gaz d'échappement est maintenu audit degré de richesse, plus court, lorsque la température représentant la température de l'adsorbant de NO_x devient plus élevée. 35
18. Procédé de purification selon la revendication 13, dans lequel ledit moyen de commande de rapport air-carburant rend le temps pendant lequel le rap- 40
- port air-carburant du gaz d'échappement est maintenu au rapport air-carburant stoechiométrique, plus court lorsque la température représentant la température de l'adsorbant de SO_x devient plus élevée. 45
19. Procédé de purification selon la revendication 1, dans lequel l'adsorbant de NO_x est dérivé par un passage en dérivation qui est branché à partir du passage d'échappement positionné entre l'adsorbant de SO_x et l'adsorbant de NO_x , le gaz d'échappement est introduit sélectivement vers soit l'adsorbant de NO_x soit le passage de dérivation, dans lequel une vanne de commutation est maintenue par un moyen de commande de vanne à une position à laquelle le gaz d'échappement circule dans l'adsorbant de NO_x lorsque le NO_x devrait être libéré de l'adsorbant de NO_x et est basculée vers une position à laquelle le gaz d'échappement circulant dans le passage de dérivation lorsque le SO_x devrait être libéré de l'adsorbant de SO_x , et ledit moyen de commande de rapport air-carburant diminue la concentration en oxygène dans le gaz d'échappement circulant dans l'adsorbant de NO_x lorsque le NO_x devrait être libéré de l'adsorbant de NO_x et rend riche le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x lorsque le SO_x devrait être libéré de l'adsorbant de SO_x . 50
20. Procédé de purification selon la revendication 19, dans lequel ledit moyen de commande de vanne et ledit moyen de commande de rapport air-carburant maintiennent la vanne de commutation à une position à laquelle le gaz d'échappement circule dans l'adsorbant de NO_x lorsque le SO_x devrait être libéré de l'adsorbant de SO_x et, en même temps, rendent riche le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x , et ensuite basculent la vanne de commutation à une position à laquelle le gaz d'échappement circule dans le passage de dérivation et, en même temps, maintiennent de façon continue le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x à l'état riche. 55
21. Procédé de purification selon la revendication 20, dans lequel ledit moyen de commande de vanne et ledit moyen de commande de rapport air-carburant maintiennent la vanne de commutation à une position à laquelle le gaz d'échappement circule dans le passage de dérivation lorsque le SO_x devrait être libéré de l'adsorbant de SO_x et, en même temps, rendent riche le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x , et ensuite basculent la vanne de commutation à la position à laquelle le gaz d'échappement circule dans l'adsorbant de NO_x et, en même temps, main-

- tiennent de façon continue le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x à l'état riche.
22. Procédé de purification selon la revendication 19, dans lequel ledit moyen de commande de vanne et ledit moyen de commande de rapport air-carburant maintiennent la vanne de commutation à une position à laquelle le gaz d'échappement circule dans l'adsorbant de NO_x, si la température représentant la température de l'adsorbant de SO_x est inférieure à la température établie prédéterminée lorsque le SO_x devrait être libéré de l'adsorbant de SO_x et, en même temps, rendent riche le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x, et basculent ensuite la vanne de commutation à une position à laquelle le gaz d'échappement circule dans le passage de dérivation et, en même temps, maintiennent de façon continue le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x à l'état riche, ledit moyen de commande de vanne et ledit moyen de commande de rapport air-carburant basculent la vanne de commutation à une position à laquelle le gaz d'échappement circule dans le passage de dérivation, si la température représentant la température de l'absorbant de SO_x est plus élevée que la température établie prédéterminée lorsque le SO_x devrait être libéré de l'adsorbant de SO_x et, en même temps, rendent riche le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x, et ensuite maintiennent la vanne de commutation à une position à laquelle le gaz d'échappement circule dans l'adsorbant de NO_x et, en même temps, maintiennent de façon continue le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x à l'état riche.
23. Procédé de purification selon la revendication 1, dans lequel la concentration en oxygène dans le gaz d'échappement circulant dans l'adsorbant de NO_x est diminuée par un moyen de commande de libération de NO_x exactement pendant une seconde période établie déterminée à l'avance de façon à libérer le NO_x de l'adsorbant de NO_x lorsque la période pendant laquelle le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de NO_x est rendu pauvre, et le NO_x est adsorbé dans l'adsorbant de NO_x, dépasse la première période établie prédéterminée.
24. Procédé de purification selon la revendication 23, dans lequel ledit moyen de commande de libération de NO_x fournit un moyen d'estimation de quantité de NO_x qui estime la quantité de NO_x adsorbé dans l'adsorbant de NO_x, et ledit moyen de commande de libération de NO_x détermine que ladite première période établie s'est écoulée lorsque la quantité de NO_x estimée par ledit moyen d'estimation dépasse une valeur maximum prédéterminée.
25. Procédé de purification selon la revendication 24, dans lequel ledit moyen d'estimation de quantité de NO_x détermine que la quantité de NO_x adsorbé dans l'adsorbant de NO_x dépasse ladite valeur maximum lorsque la valeur cumulative du régime de rotation du moteur dépasse une valeur établie prédéterminée.
26. Procédé de purification selon la revendication 25, dans lequel ledit moyen d'estimation de quantité de NO_x estime la quantité de NO_x adsorbé dans l'adsorbant de NO_x d'après la quantité de NO_x contenue dans les gaz d'échappement lorsque le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de NO_x est pauvre, estime la quantité de NO_x libéré de l'adsorbant de NO_x sur la base du degré de richesse dudit gaz d'échappement lorsque le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de NO_x est riche et sur la base de la température représentant la température de l'adsorbant de NO_x, et estime la quantité de NO_x adsorbé de façon continue dans l'adsorbant de NO_x d'après cette libération estimée de NO_x.
27. Procédé de purification selon la revendication 26, dans lequel ledit moyen de commande de libération de NO_x détermine que ladite période établie s'est écoulée lorsque la quantité de NO_x estimée par ledit moyen d'estimation de NO_x devient plus petite qu'une valeur minimum prédéterminée.
28. Procédé de purification selon la revendication 1, dans lequel le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x est rendu riche par un moyen de commande de libération de SO_x exactement pendant une seconde période établie déterminée à l'avance de façon à libérer le SO_x de l'adsorbant de SO_x lorsque la période pendant laquelle le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x est rendu pauvre et le SO_x est adsorbé dans l'adsorbant de SO_x, dépasse la première période établie prédéterminée.
29. Procédé de purification selon la revendication 28, dans lequel la quantité de NO_x adsorbé dans l'adsorbant de SO_x est estimée par un moyen d'estimation de quantité de SO_x fourni par ledit moyen de commande de libération de SO_x, et ledit moyen de commande de libération de SO_x détermine que ladite première période établie s'est écoulée lorsque la quantité de SO_x estimée par ledit moyen d'estimation de quantité de SO_x dépasse une valeur maximum prédéterminée, et détermine que ladite

- seconde période s'est écoulée lorsque la quantité de SO_x estimée par ledit moyen d'estimation de quantité de SO_x devient plus petite qu'une valeur maximum prédéterminée.
30. Procédé de purification selon la revendication 29, dans lequel ledit moyen d'estimation de quantité de SO_x estime la quantité de SO_x absorbé dans l'adsorbant de SO_x d'après la quantité de SO_x contenue dans le gaz d'échappement lorsque le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x est pauvre, et estime la quantité de SO_x libérée de l'adsorbant de SO_x sur la base du degré de richesse dudit gaz d'échappement lorsque le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x est riche et sur la base de la température représentant la température de l'adsorbant de SO_x, et estime la quantité de SO_x absorbé de façon continue dans l'adsorbant de SO_x d'après cette quantité de SO_x libérée. 20
31. Procédé de purification selon la revendication 1, dans lequel ledit moyen de commande de rapport air-carburant commande le rapport air-carburant du gaz d'échappement dans le passage d'échappement et rend riche le rapport air-carburant du gaz d'échappement circulant dans l'adsorbant de SO_x lorsque le SO_x devrait être libéré de l'adsorbant de SO_x. 25
32. Procédé de purification selon la revendication 31, dans lequel ledit moyen de commande de rapport air-carburant fait passer un agent de réduction dans le passage d'échappement lorsque le SO_x devrait être libéré de l'adsorbant de SO_x. 35
33. Procédé de purification selon la revendication 32, dans lequel en tant qu'agent de réduction, un agent est choisi composé d'au moins un élément sélectionné à partir de l'essence, de l'isooctane, de l'hexane, de l'heptane, du butane, du propane, du pétrole léger et du pétrole lampant. 40
34. Dispositif de purification d'échappement destiné à exécuter le procédé selon la revendication 1, dans lequel l'adsorbant de NO_x contient au moins un élément sélectionné à partir des métaux alcalins constitués du potassium, du sodium, du lithium, du cézium et des éléments alcalino-terreux constitués du baryum et du calcium, et des terres rares constituées du lanthane, de l'yttrium et du platine. 45
35. Dispositif de purification d'échappement destiné à exécuter le procédé selon la revendication 1, dans lequel l'adsorbant de SO_x contient au moins un élément sélectionné à partir du cuivre, du fer, du manganèse, du nickel, du sodium, de l'étain, du titane, du lithium et de l'oxyde de titane. 50
36. Dispositif de purification d'échappement destiné à exécuter le procédé selon la revendication 1, dans lequel l'adsorbant de SO_x contient le platine. 55
37. Dispositif de purification d'échappement destiné à exécuter le procédé selon la revendication 2, dans lequel l'adsorbant de SO_x et l'adsorbant de NO_x sont disposés dans un carter.
38. Dispositif de purification d'échappement destiné à exécuter le procédé selon la revendication 19, dans lequel il est prévu un passage de dérivation qui est branché à partir de la position de passage d'échappement entre l'adsorbant de SO_x et l'adsorbant de NO_x, une vanne de commutation est agencée au niveau de la partie dérivée du passage de dérivation depuis le passage d'échappement et un moyen de commande de vanne est prévu, lequel forme la commande de commutation de ladite vanne de commutation.

Fig.1

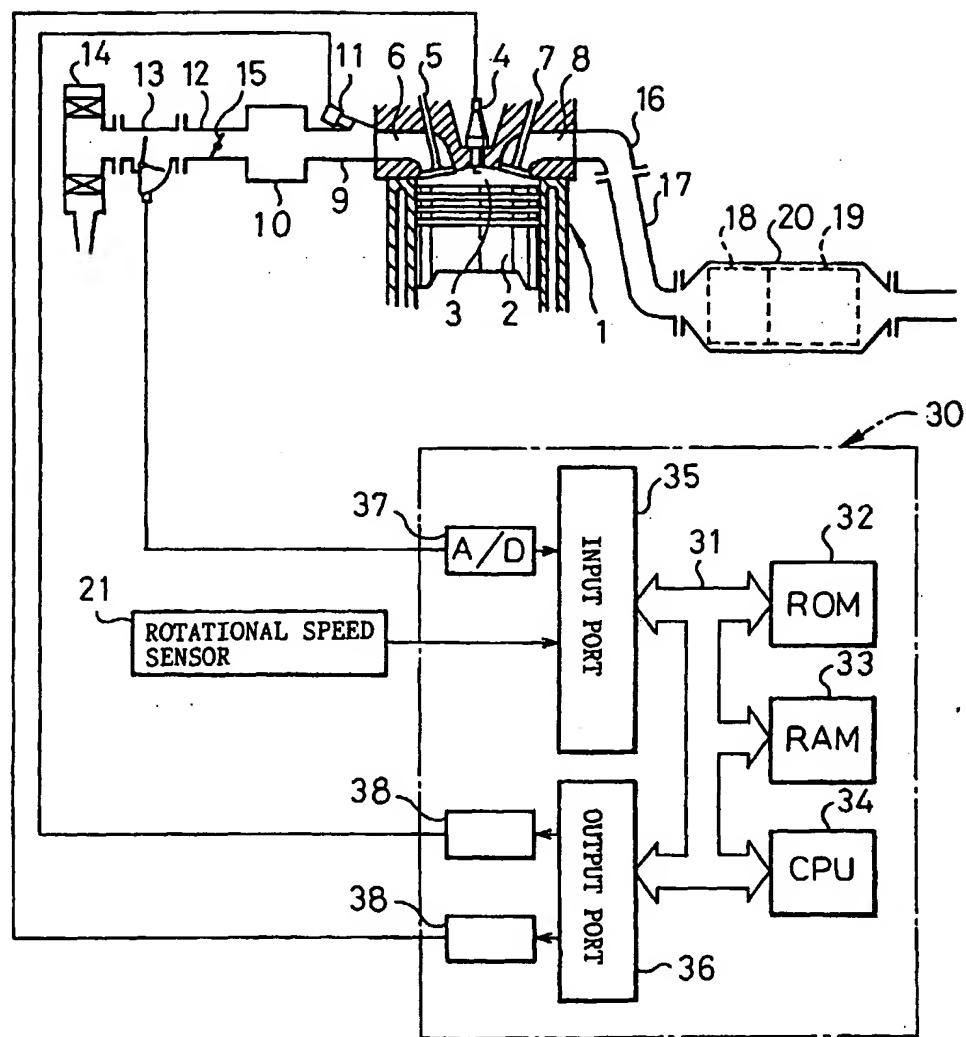


Fig. 2

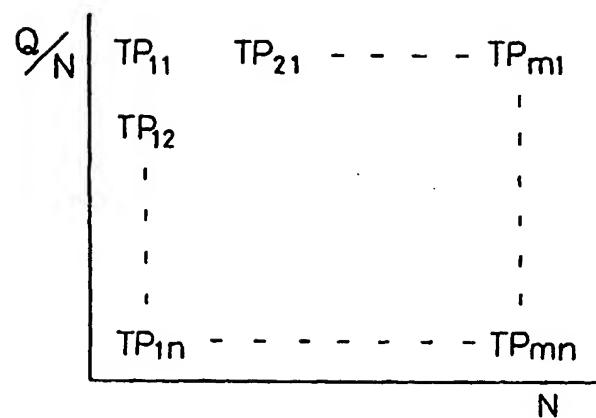


Fig. 3

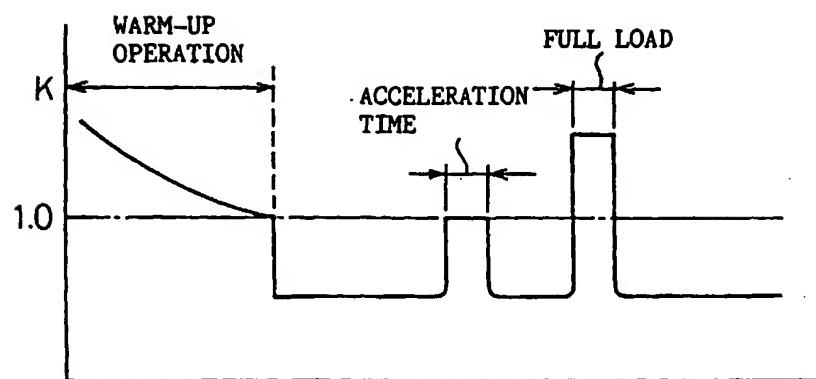


Fig. 4

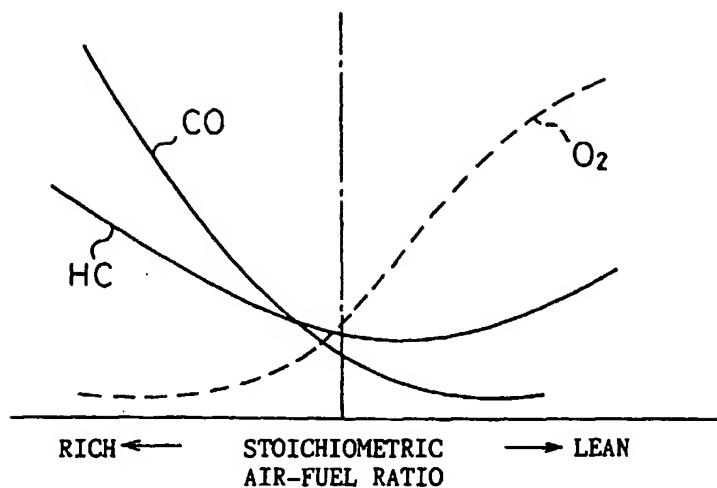


Fig. 5A

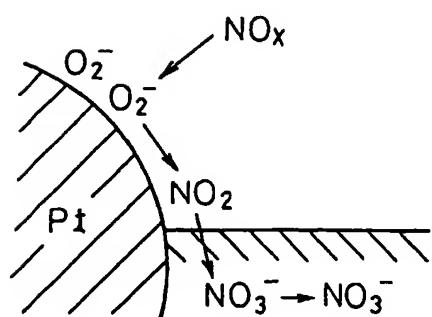


Fig. 5B

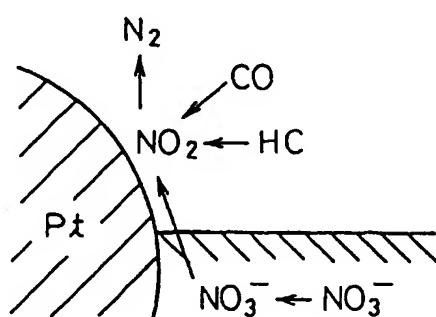


Fig. 6

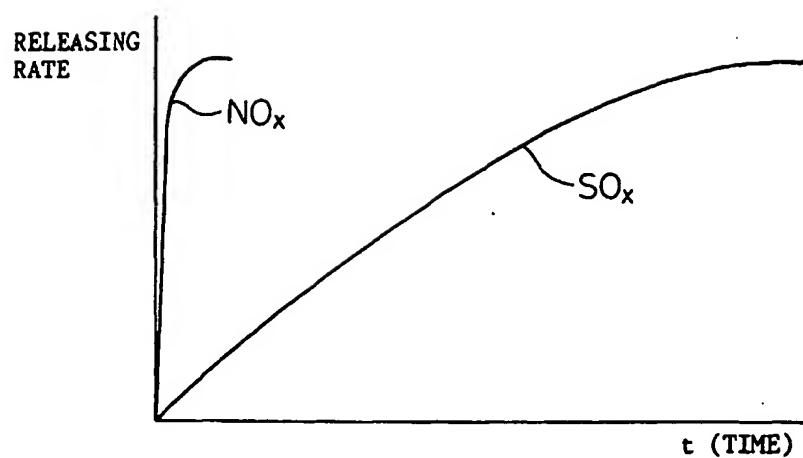


Fig.7

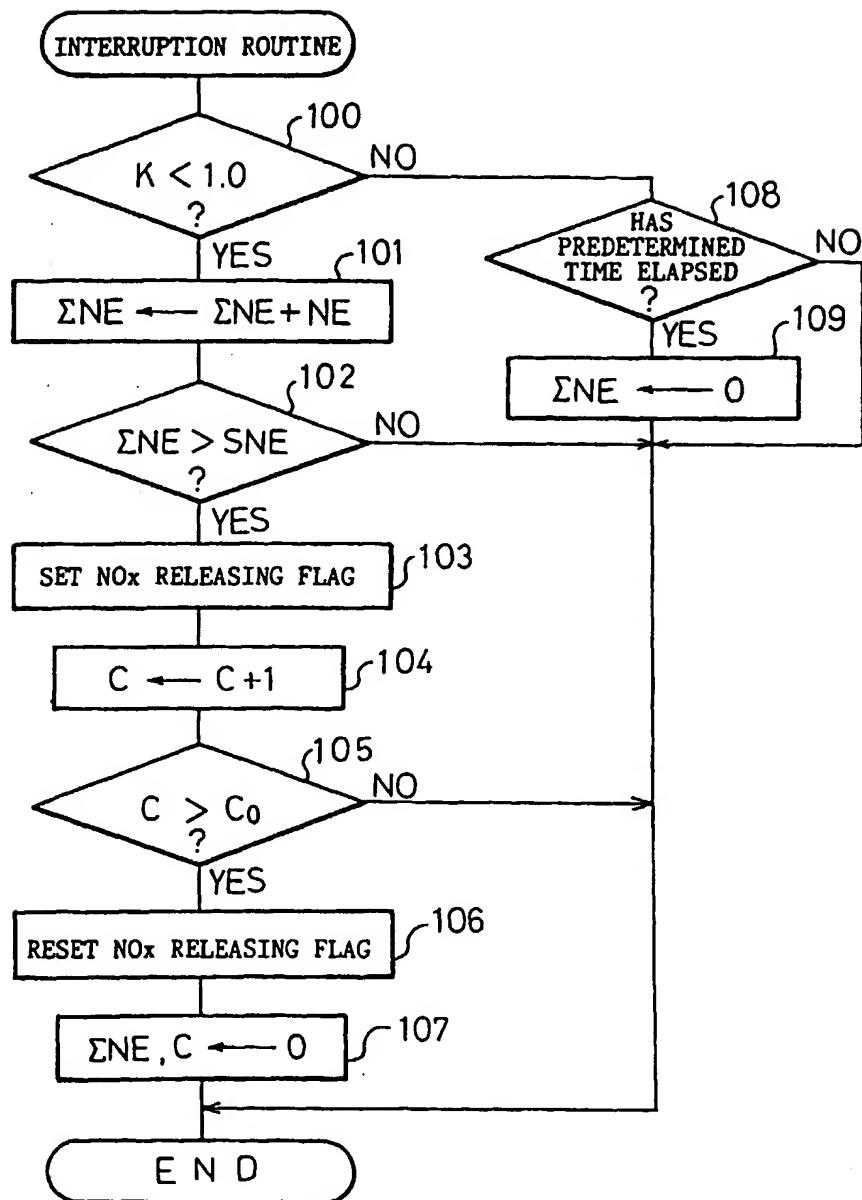


Fig. 8

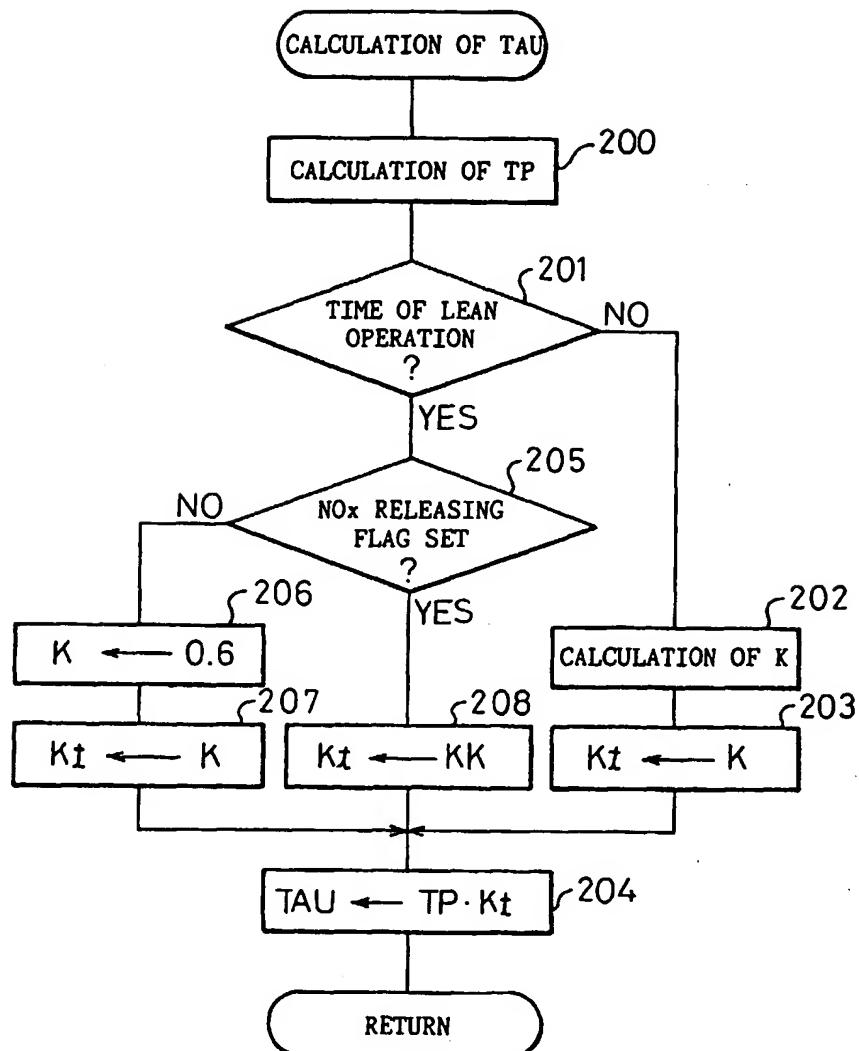


Fig. 9

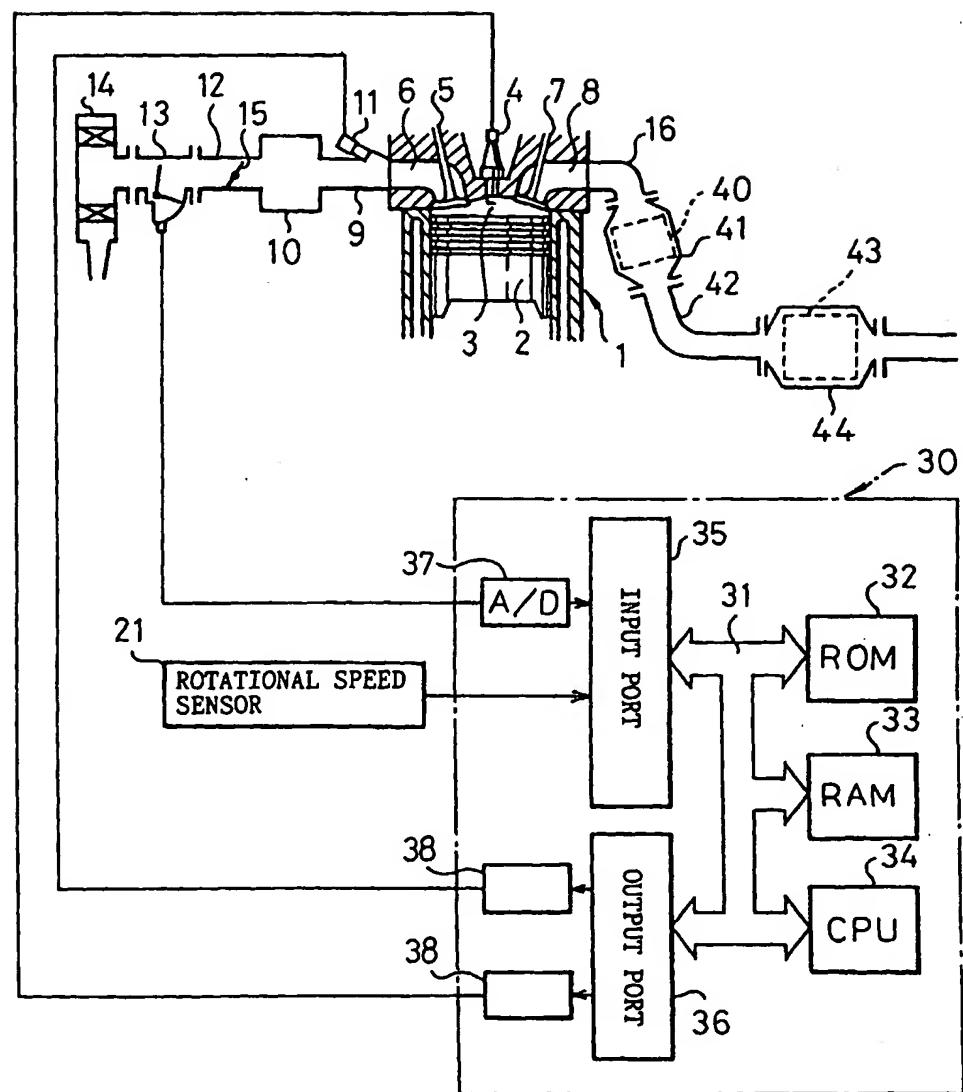


Fig.10

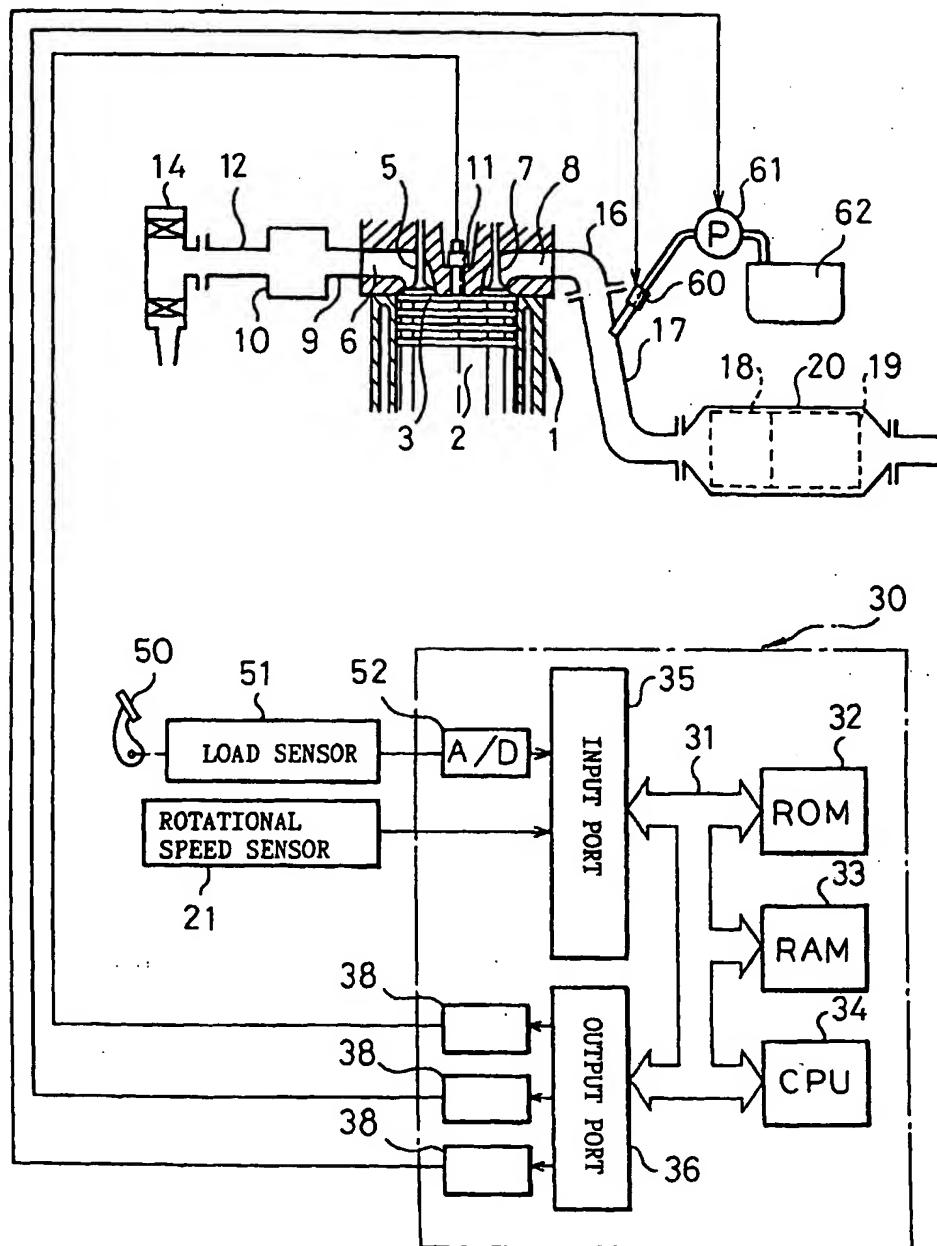


Fig.11

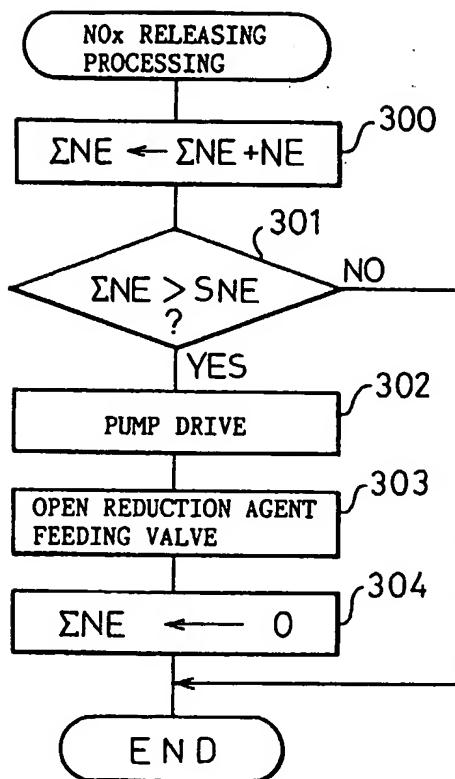


Fig.12

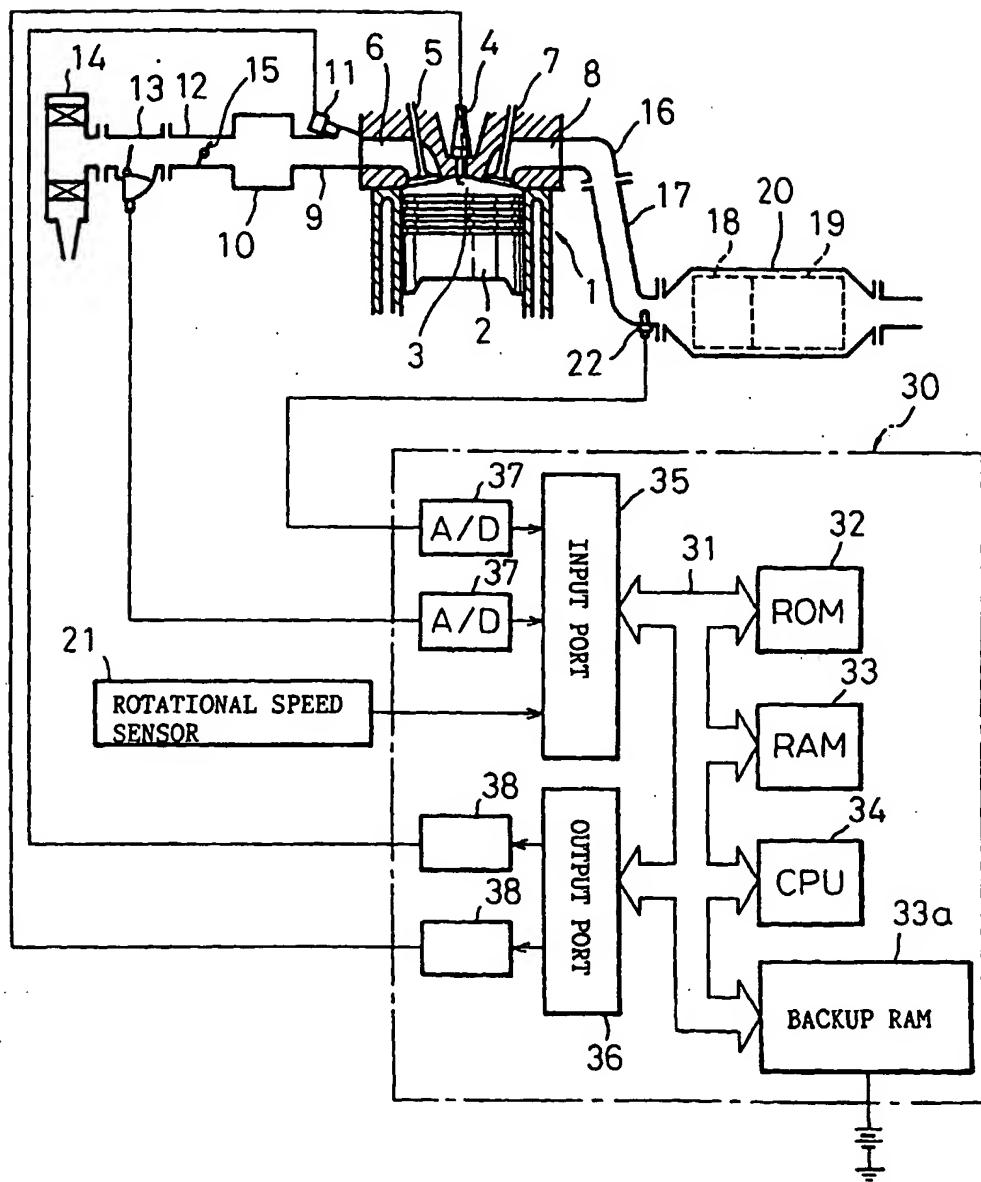


Fig.13

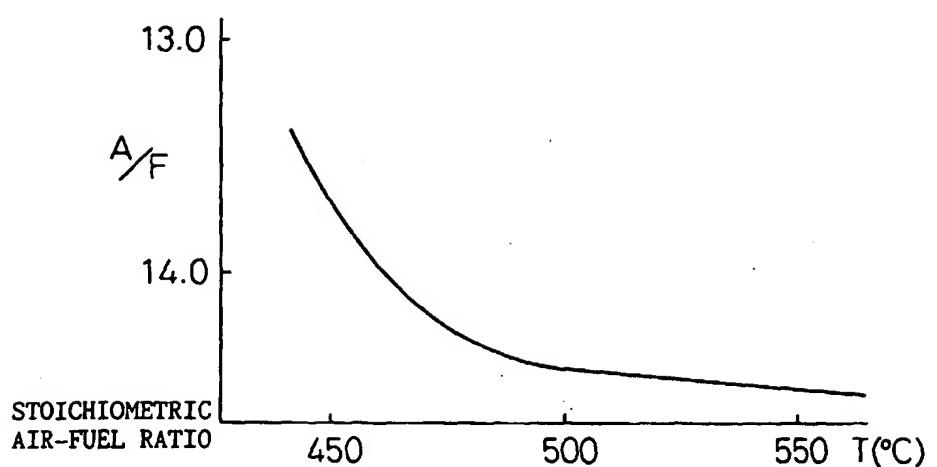


Fig.14

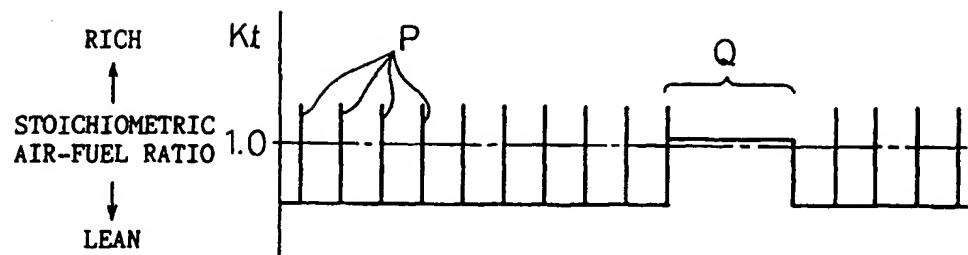


Fig.15

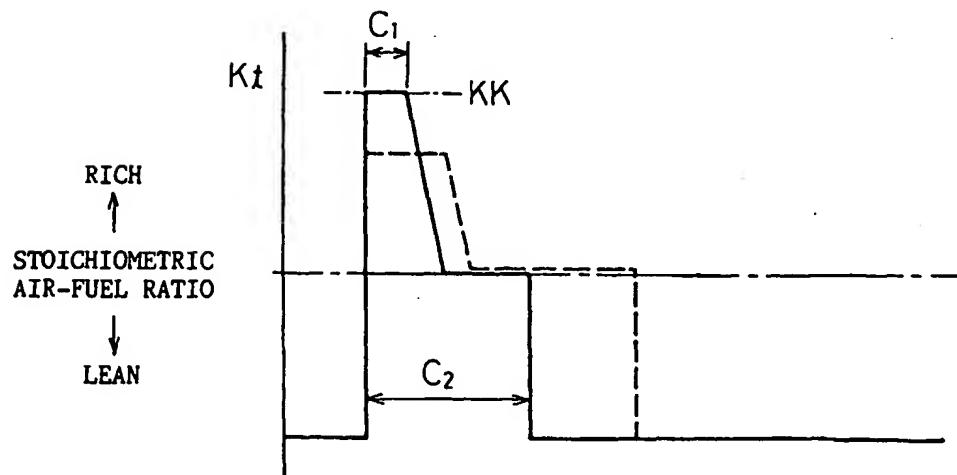


Fig.16A

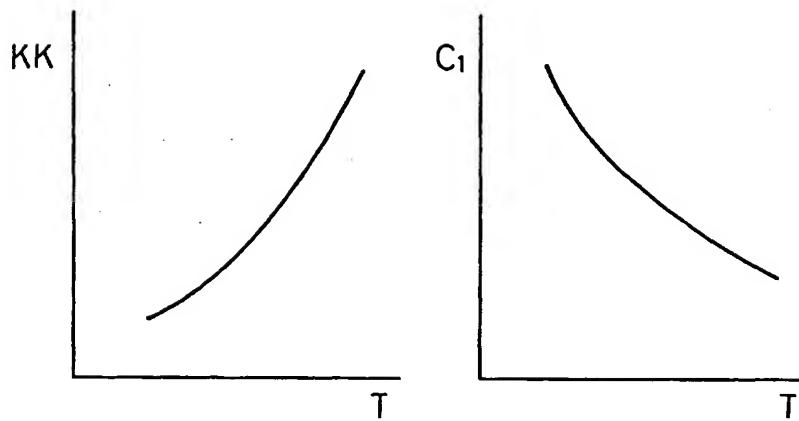


Fig.16B

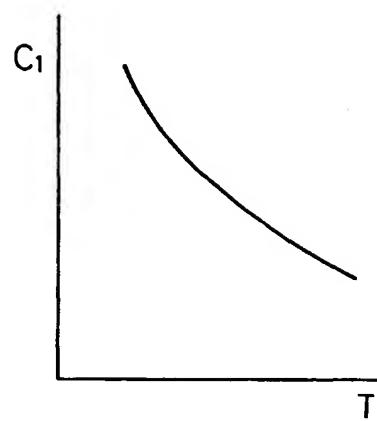


Fig.16C

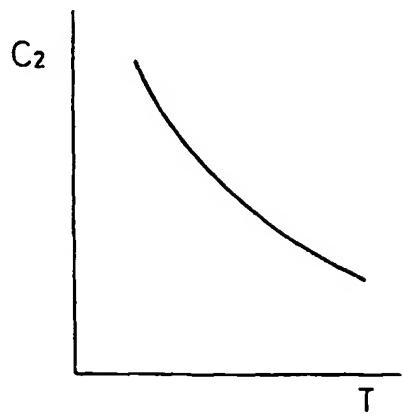


Fig.17

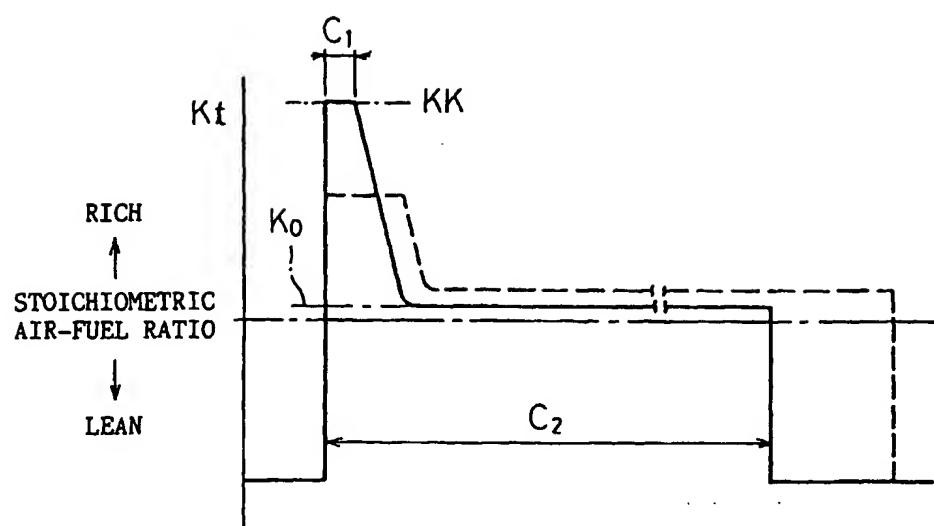


Fig.18A

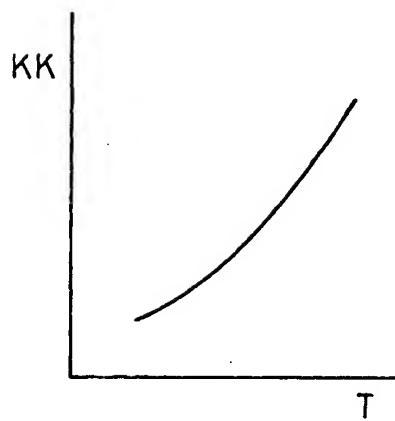


Fig.18B

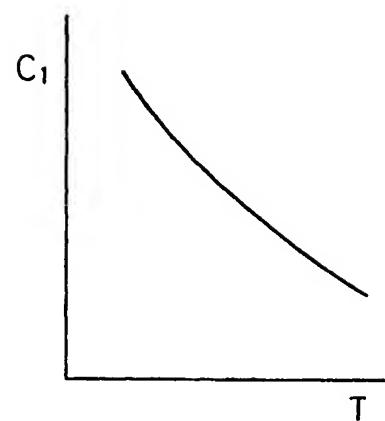


Fig.18C

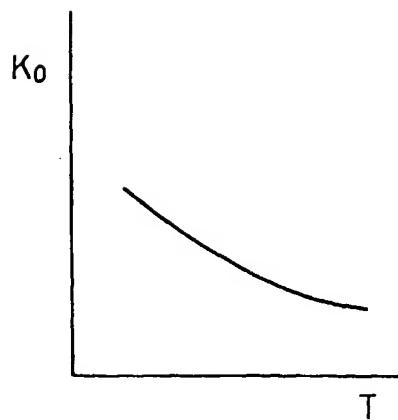


Fig.18D

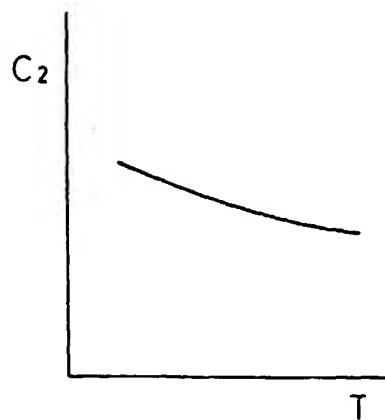


Fig.19

Q	T ₁₁	T ₂₁	- - - - -	T _{m1}
	T ₁₂			'
	'			'
	'			'
	'			'
	T _{1n}	- - - - -	- - T _{mn}	
				N

Fig. 20

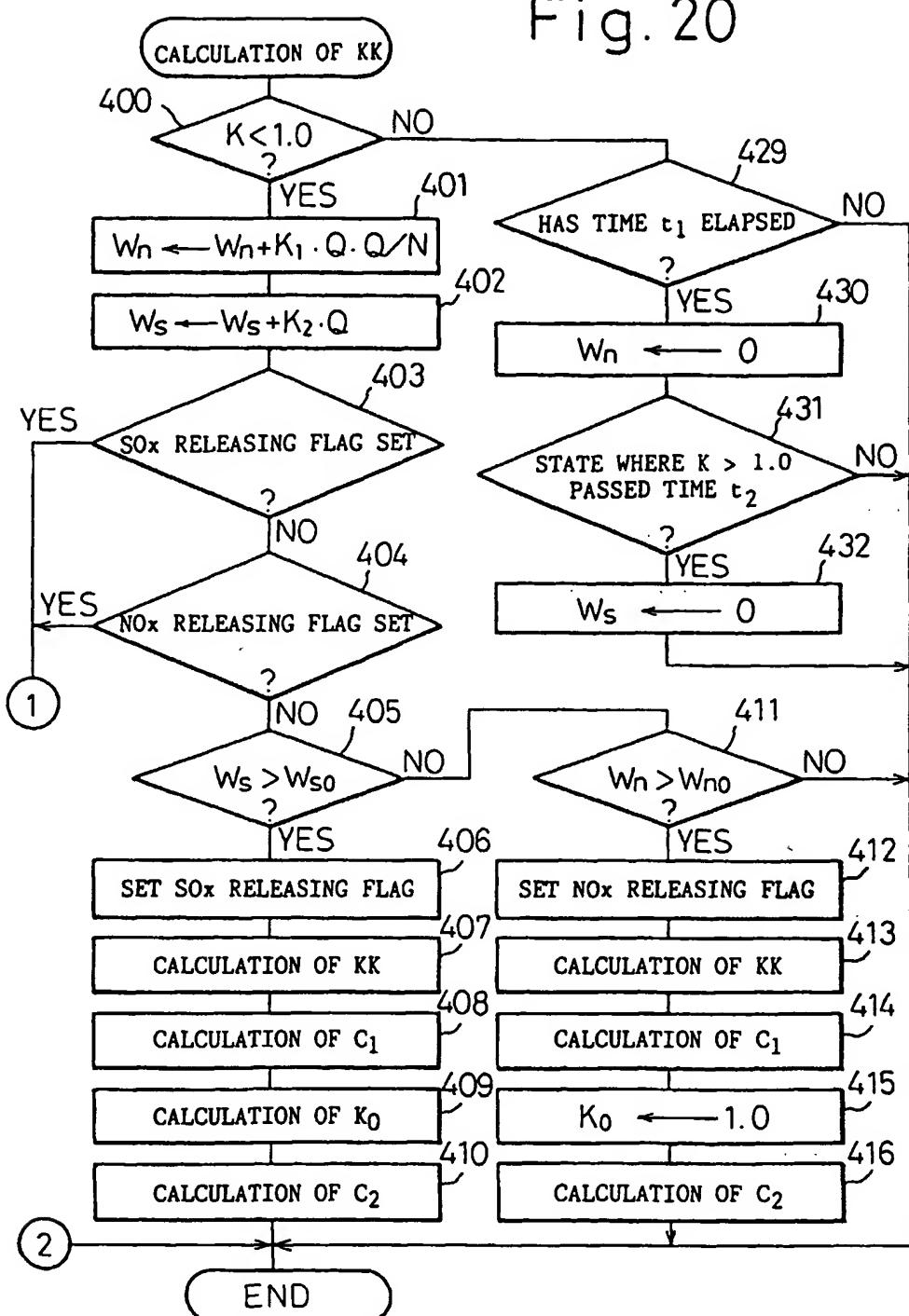


Fig.21

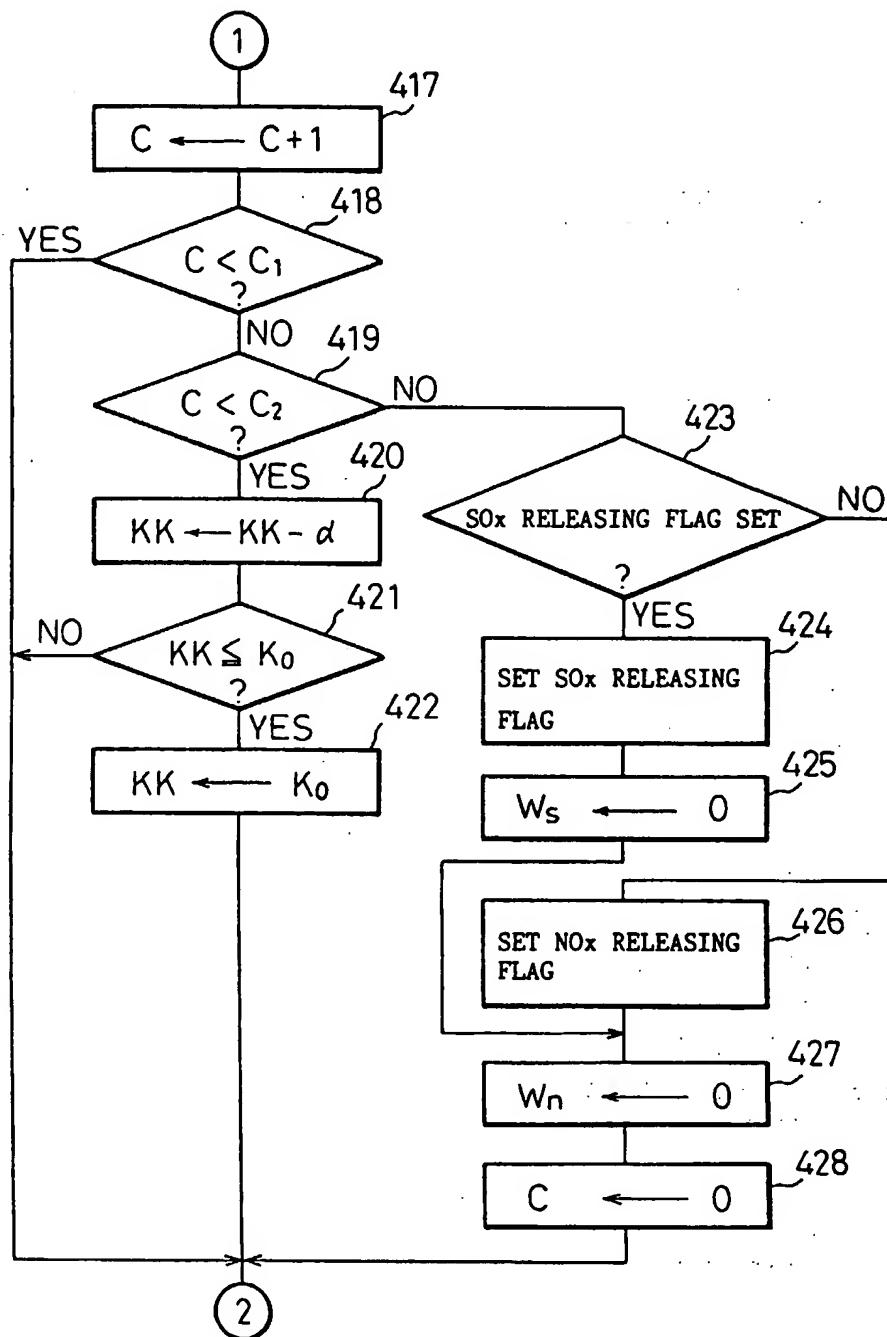


Fig.22

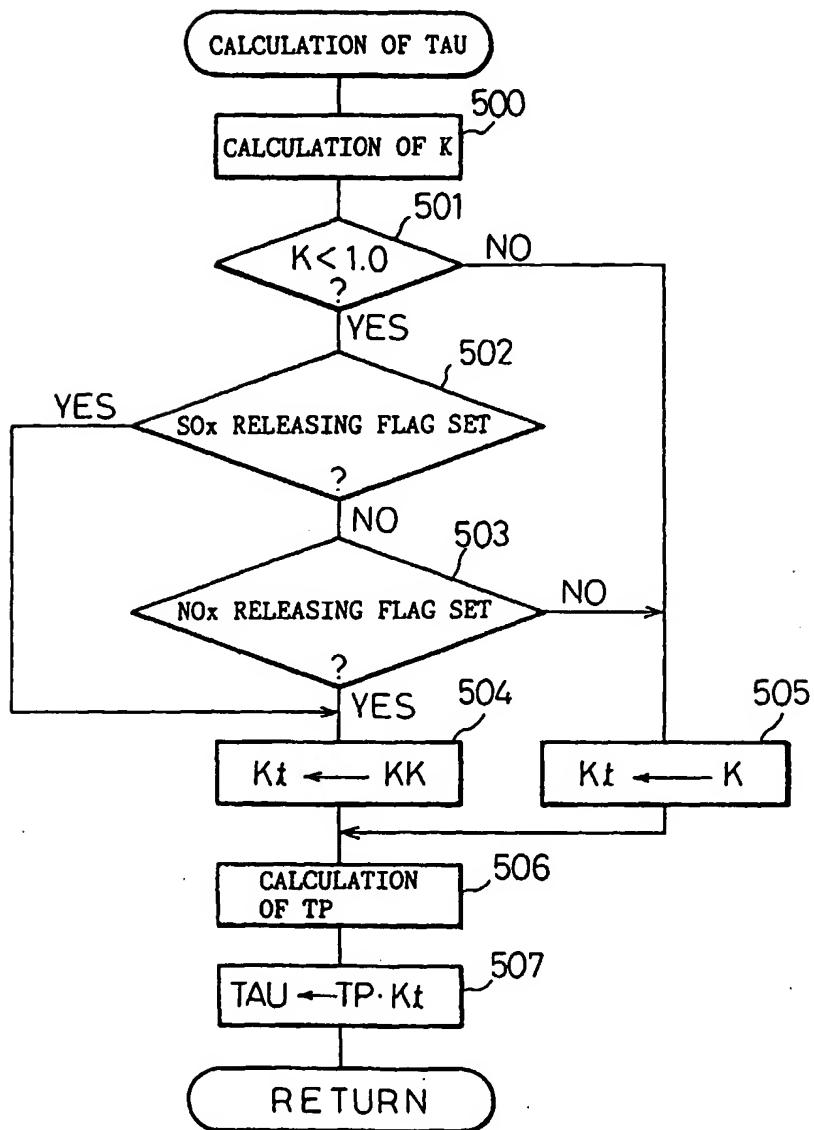


Fig. 23

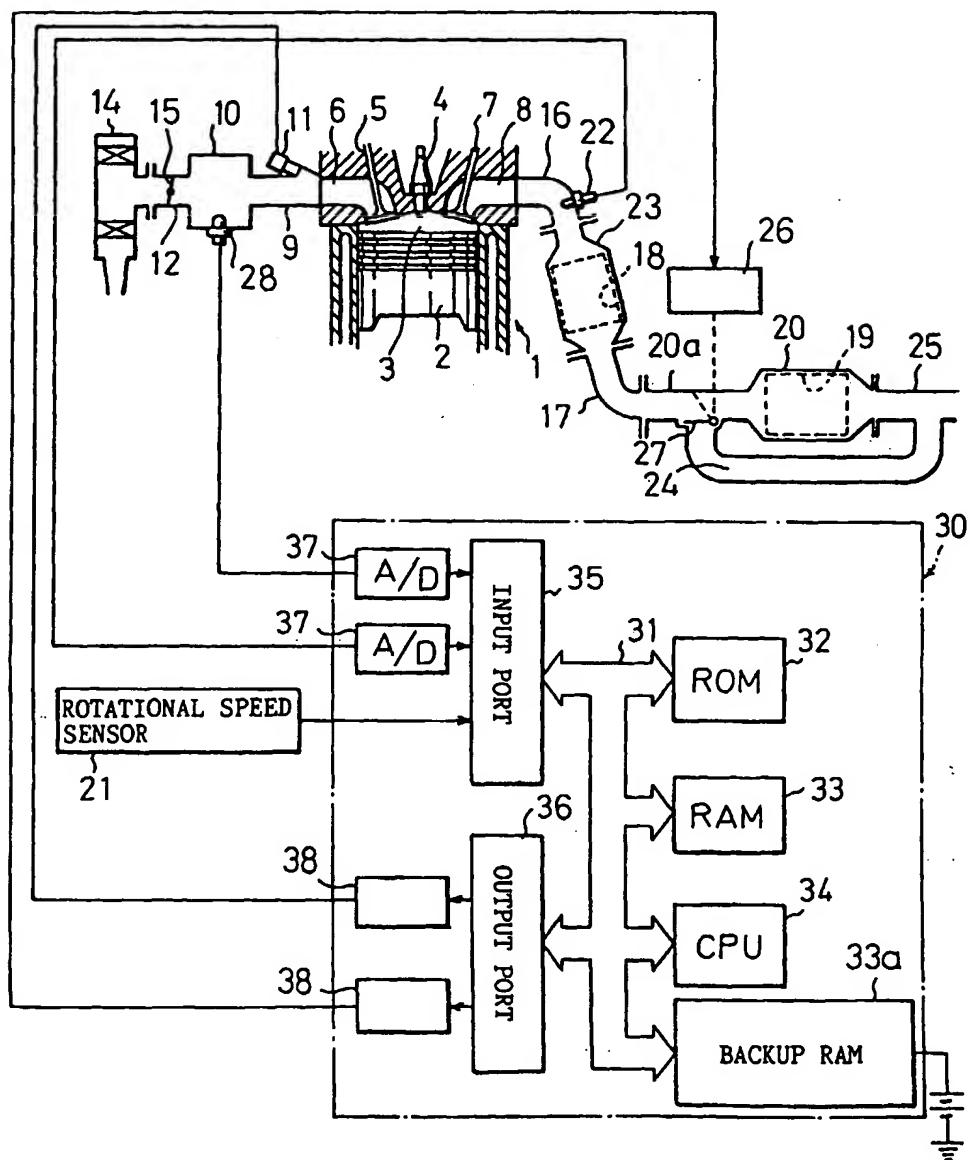


Fig. 24

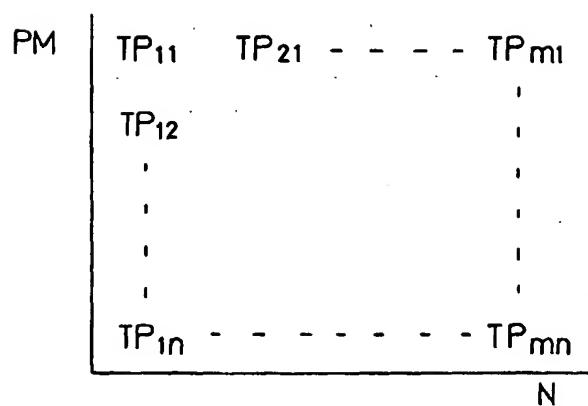


Fig. 25

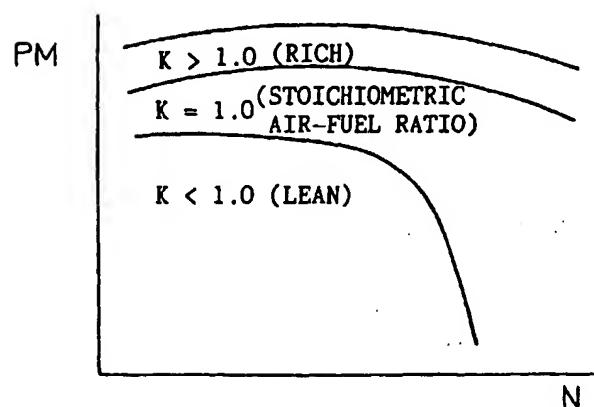


Fig. 26A

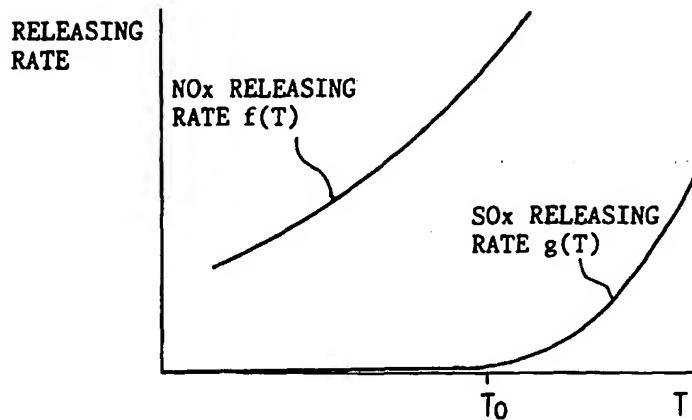


Fig. 26B

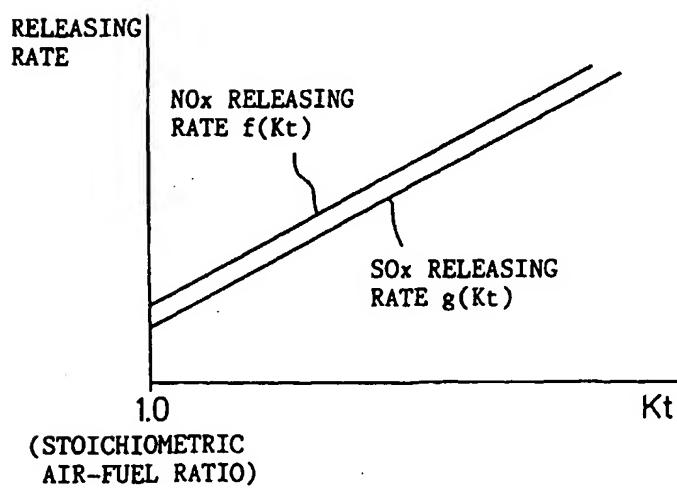


Fig. 27A

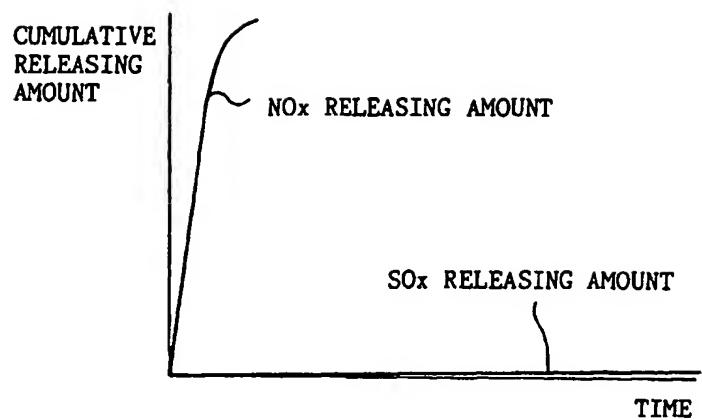


Fig. 27B

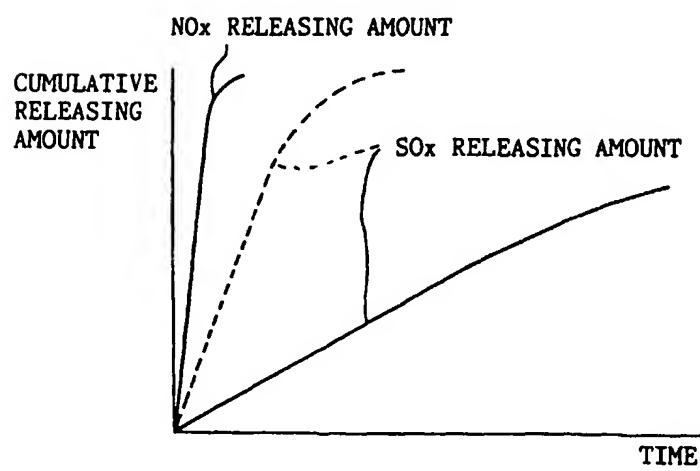


Fig. 28

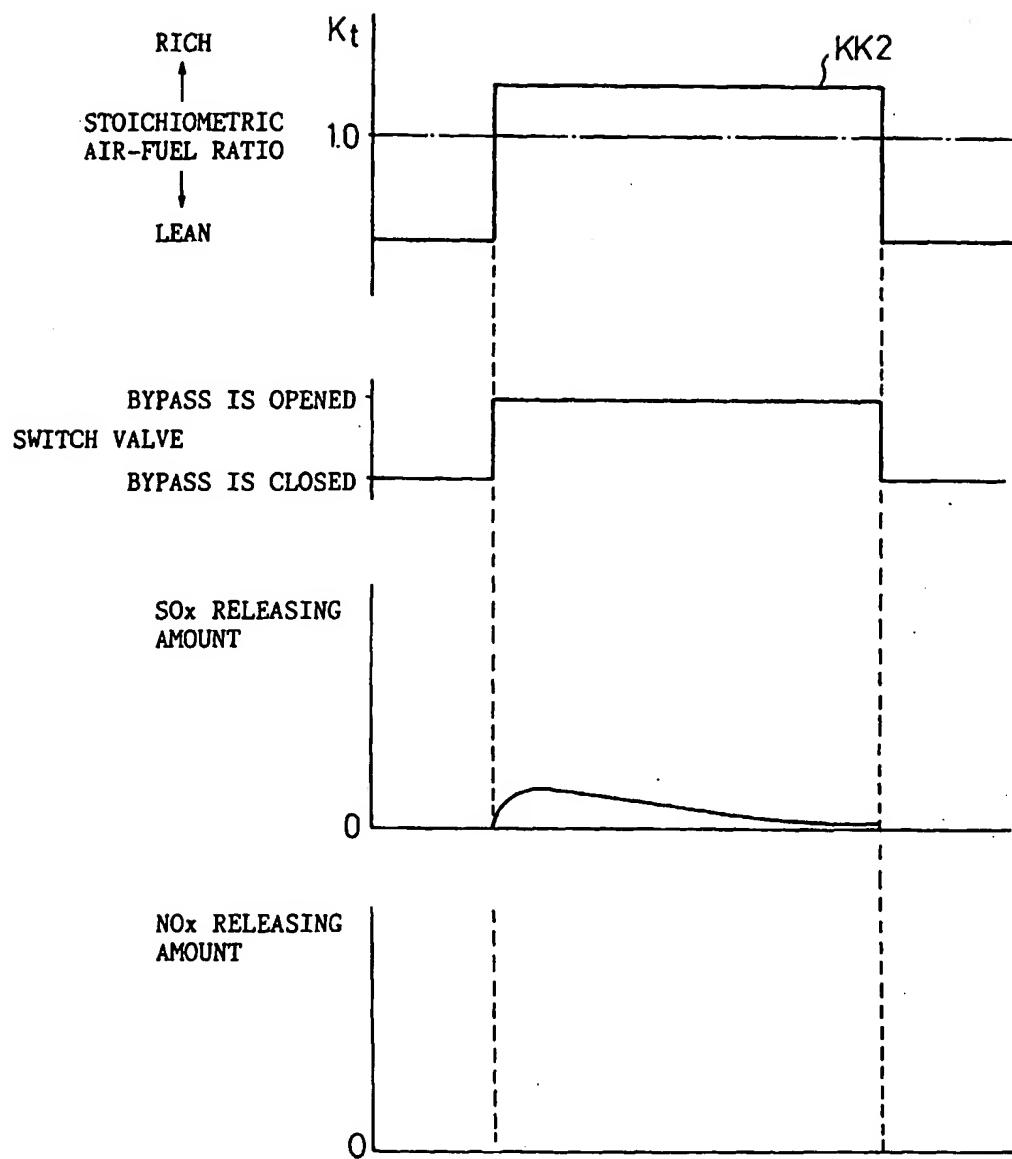


Fig. 29

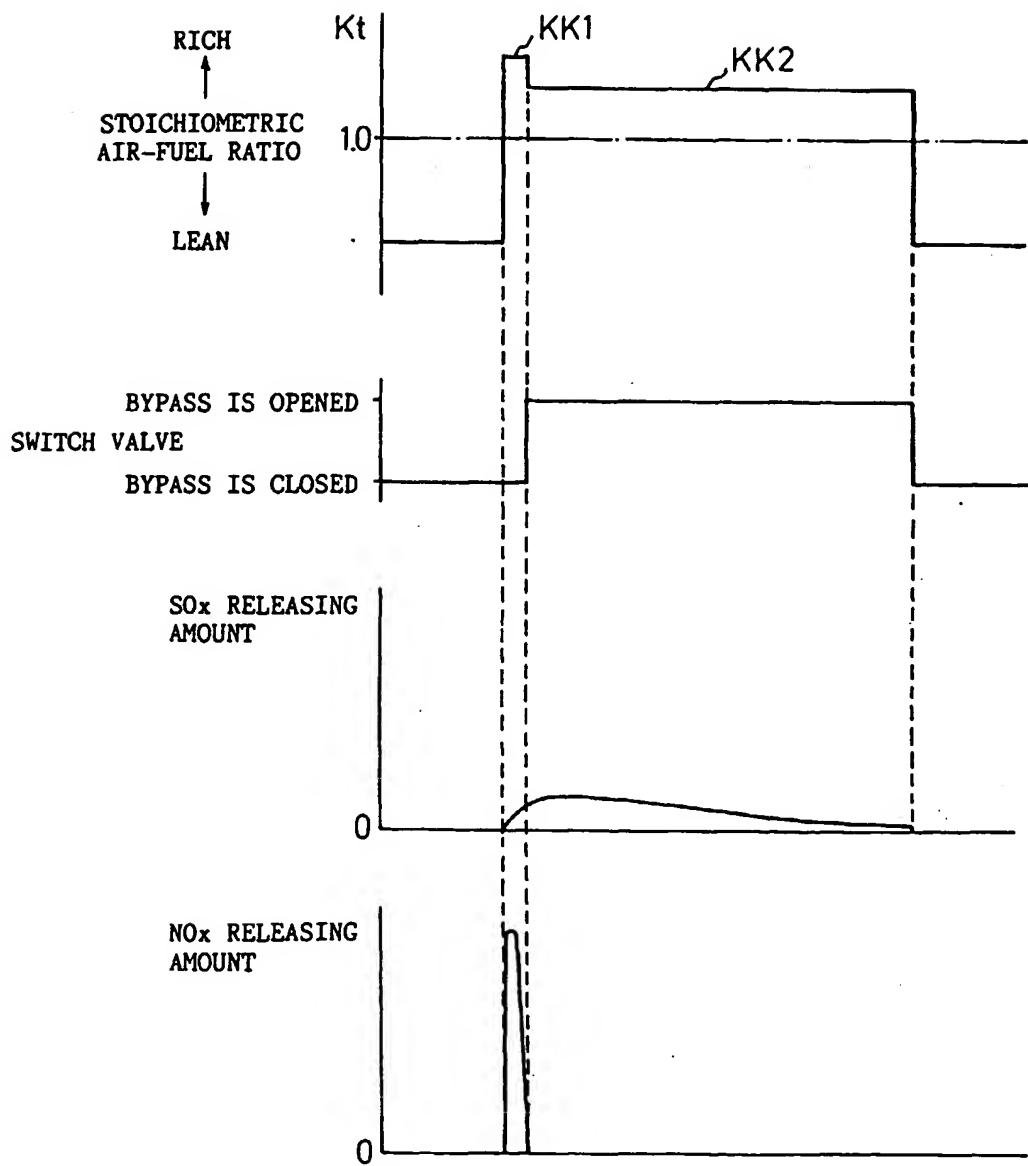


Fig. 30

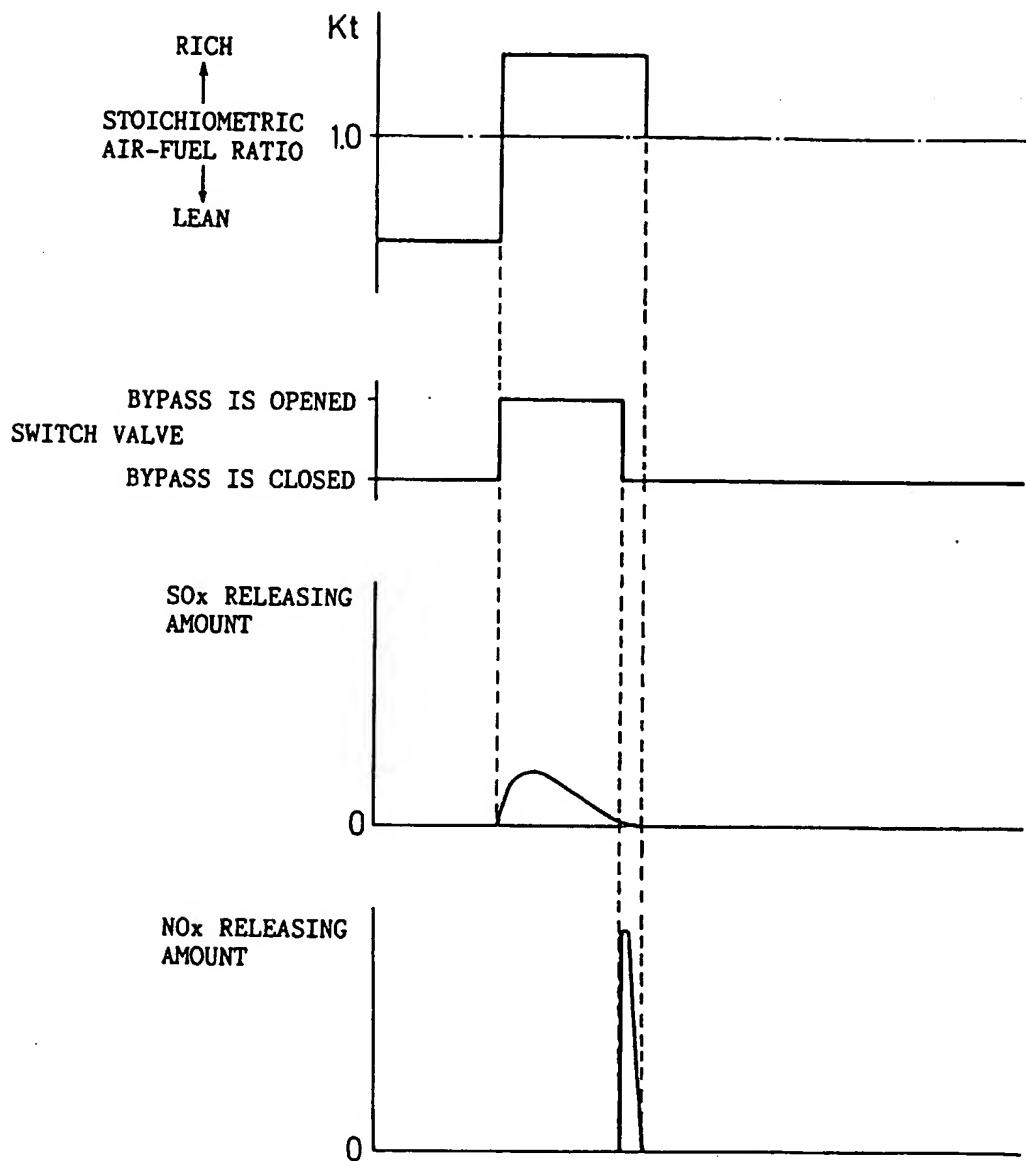


Fig. 31

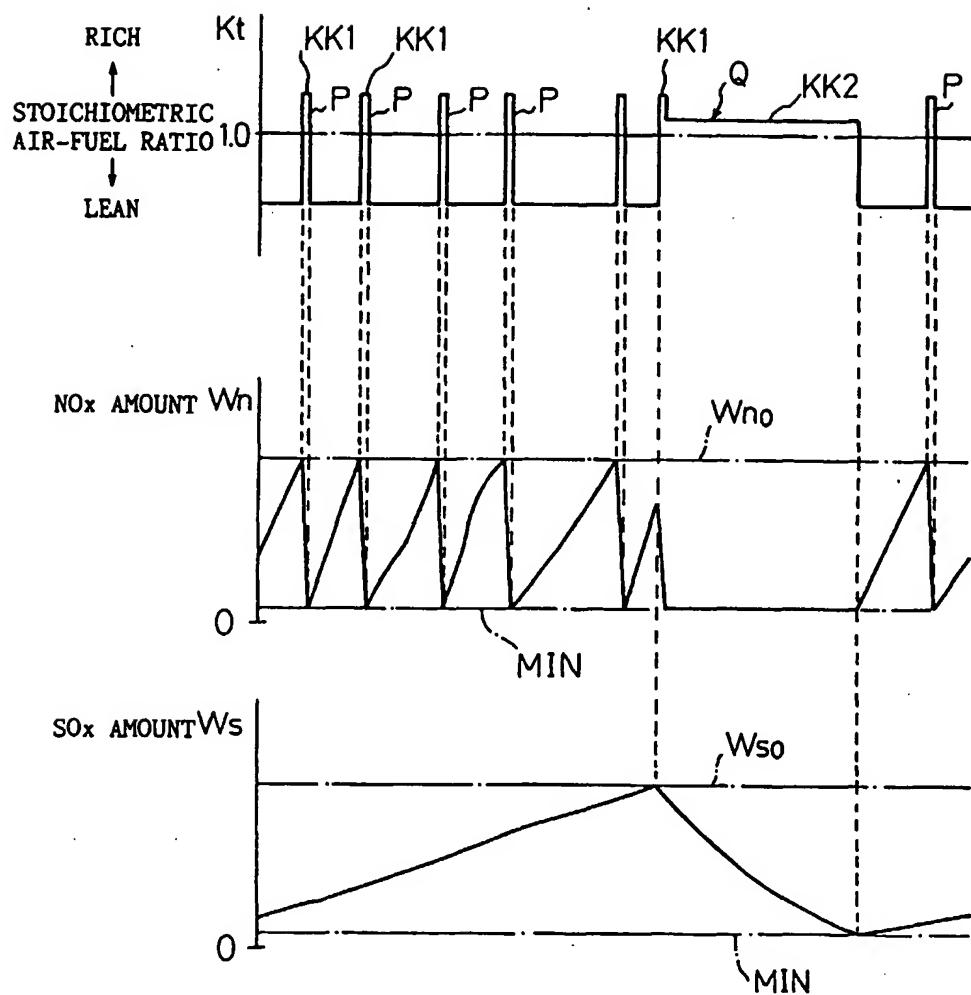


Fig. 32A

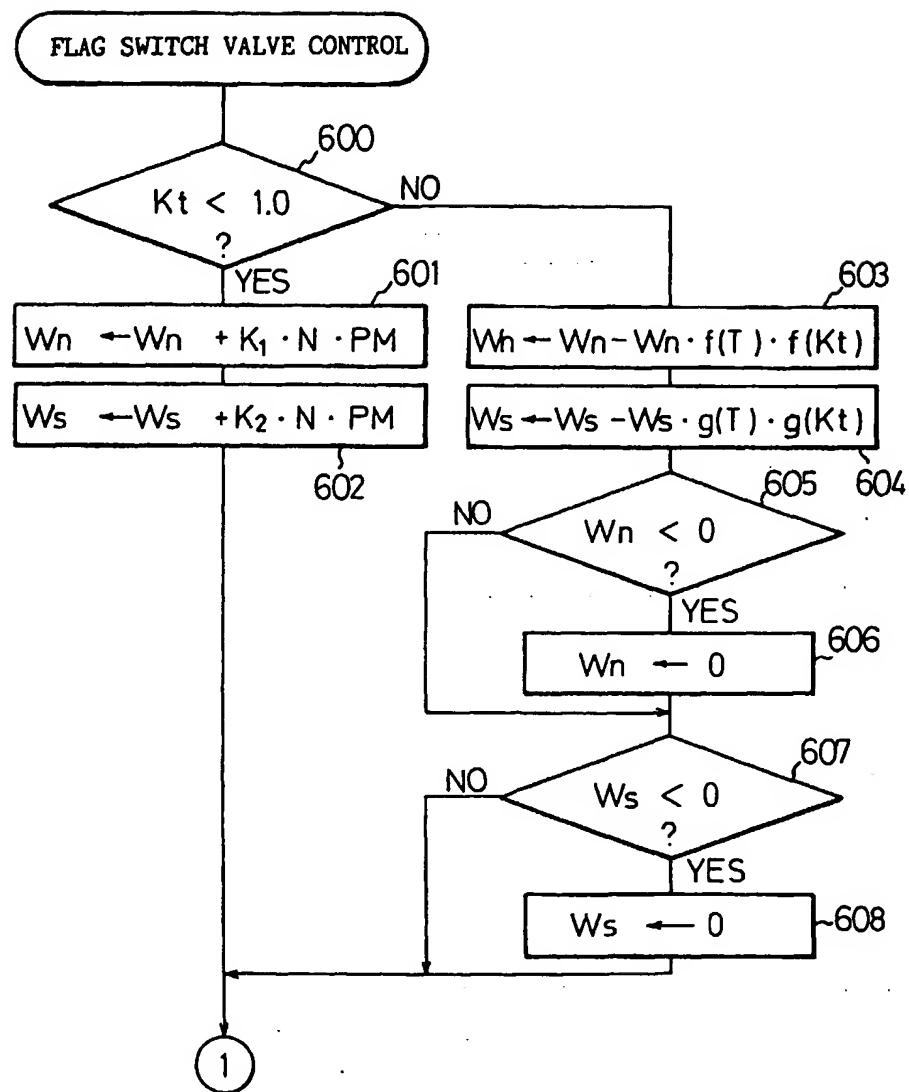


Fig. 32B

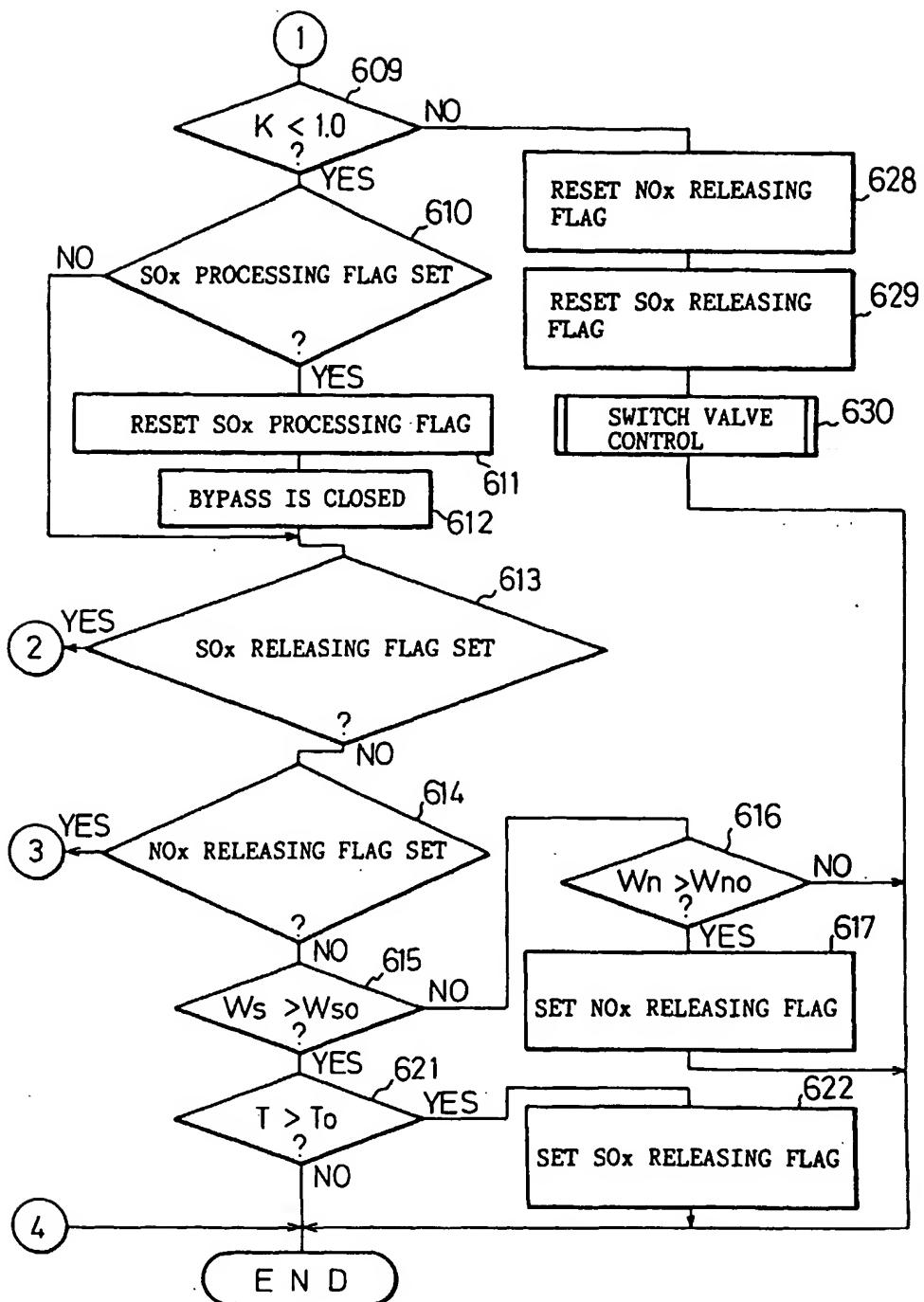


Fig.32C

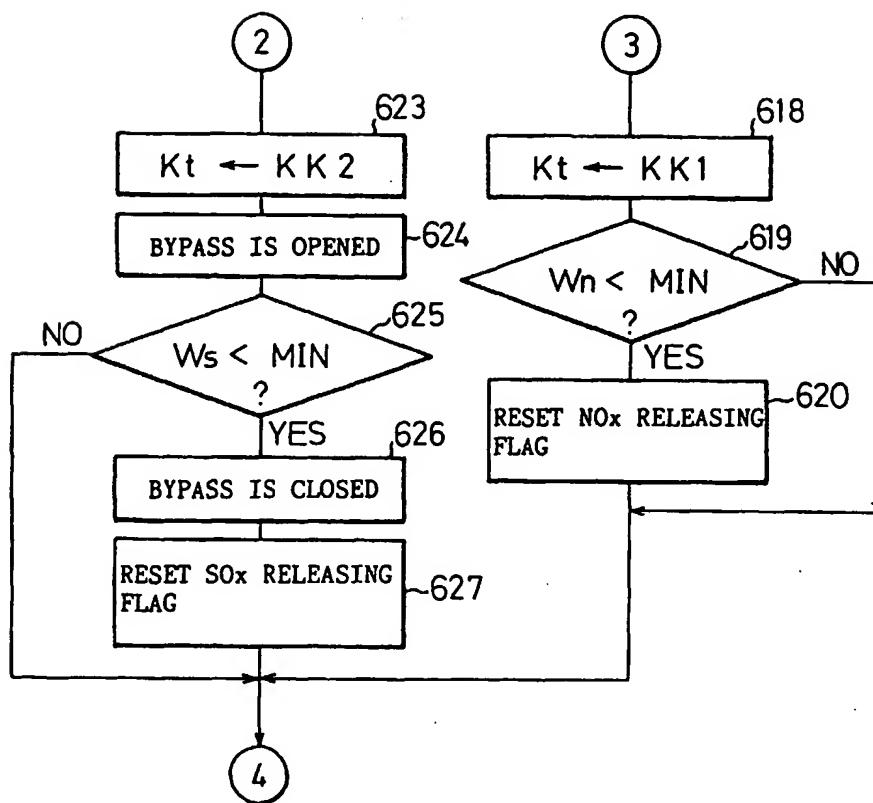


Fig.32D

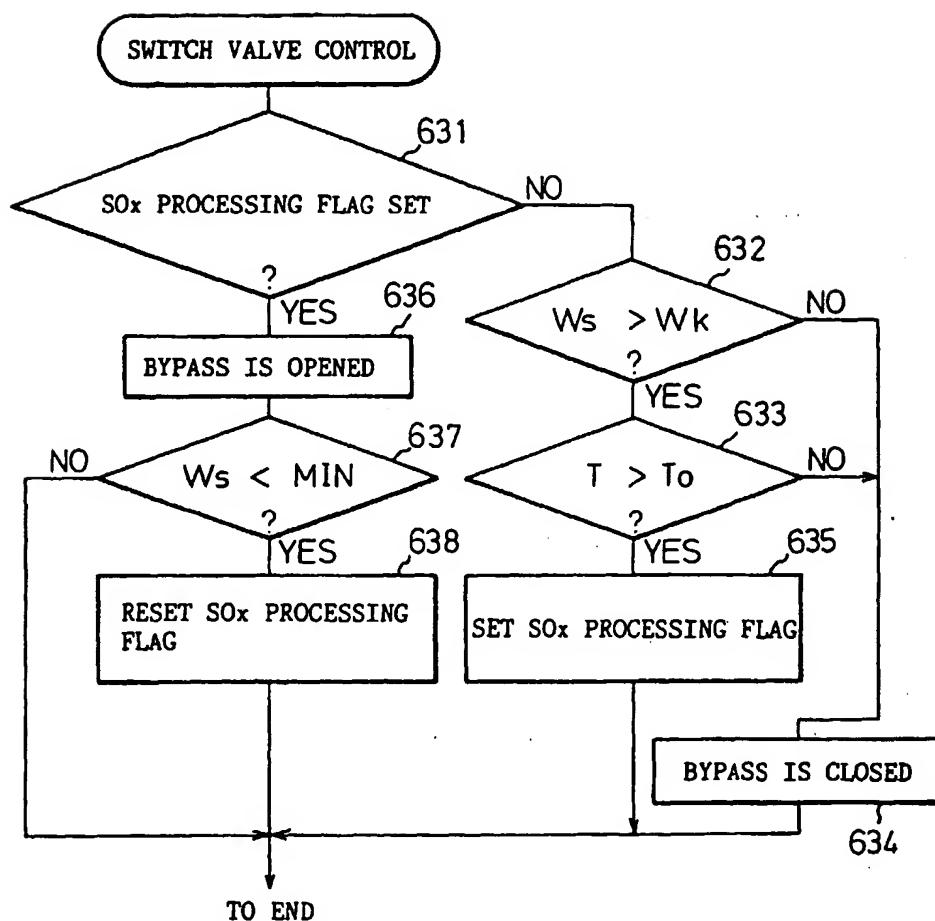


Fig.33

PM	T_{11}	T_{21}	- - - - -	T_{m1}
	T_{12}			'
	'			'
	'			'
	'			'
	T_{1n}	- - - - -	- - -	T_{mn}

N

Fig. 34

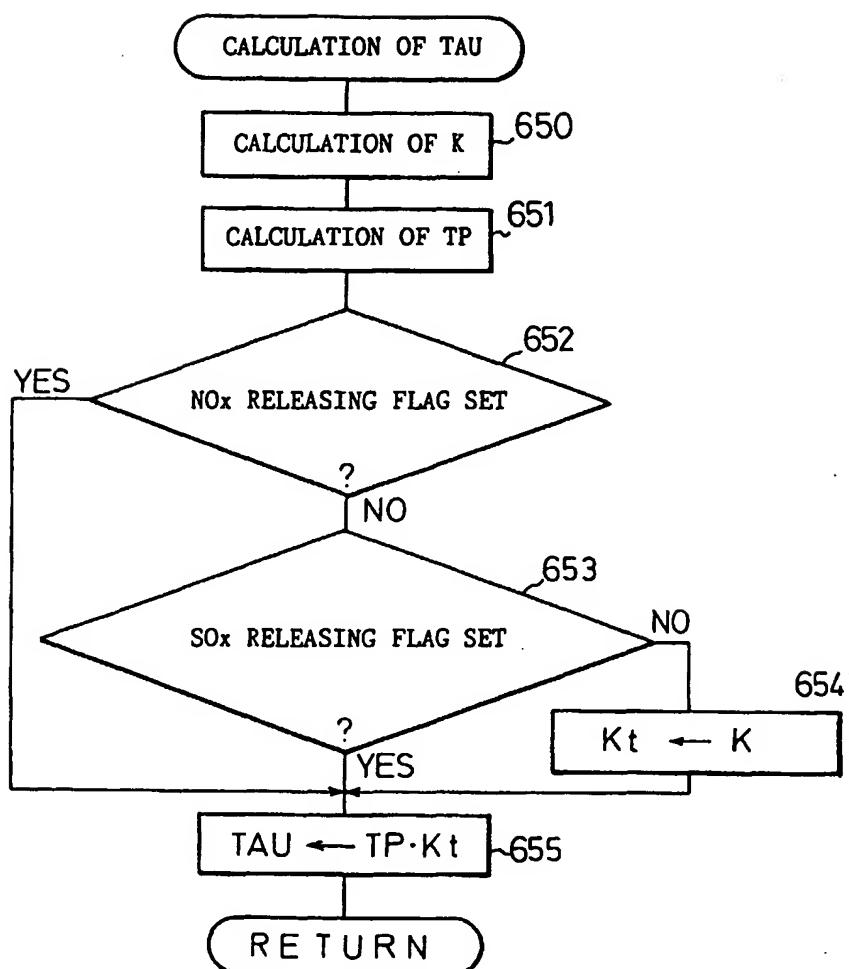


Fig. 35A

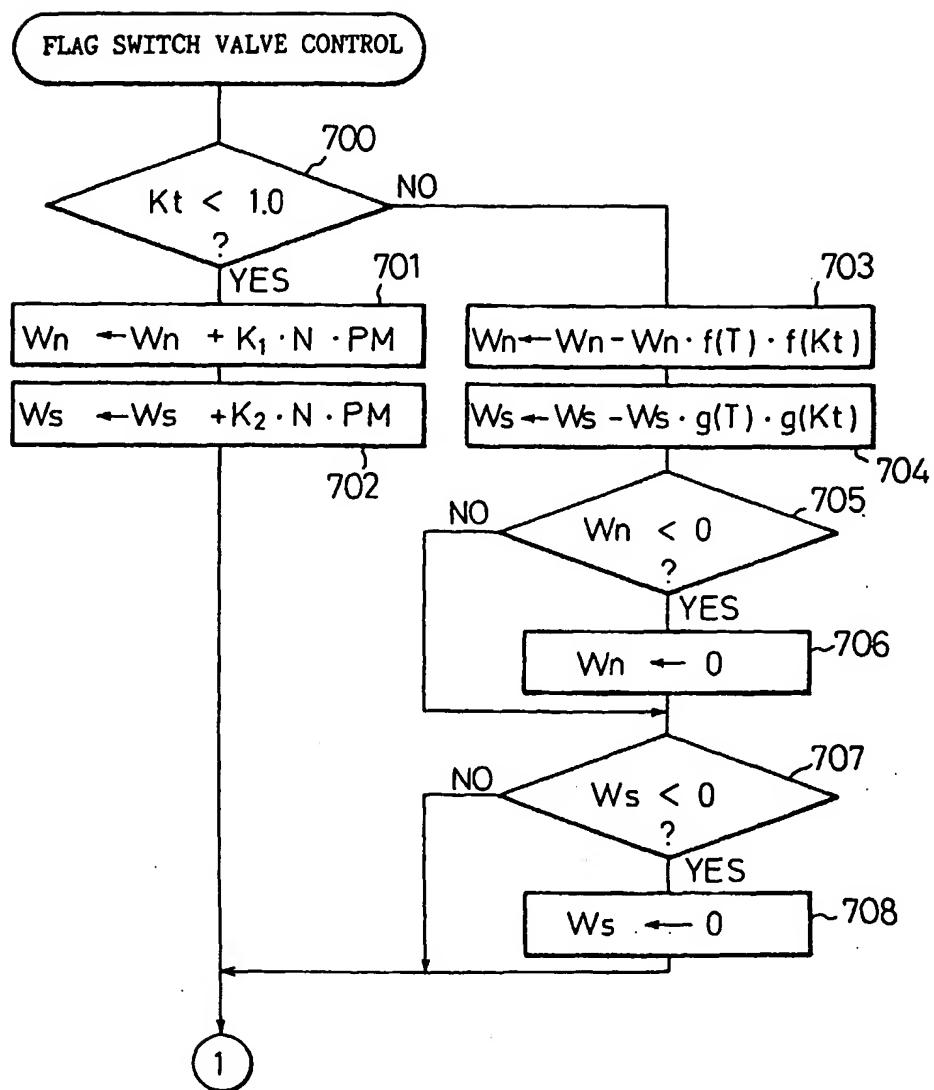


Fig. 35B

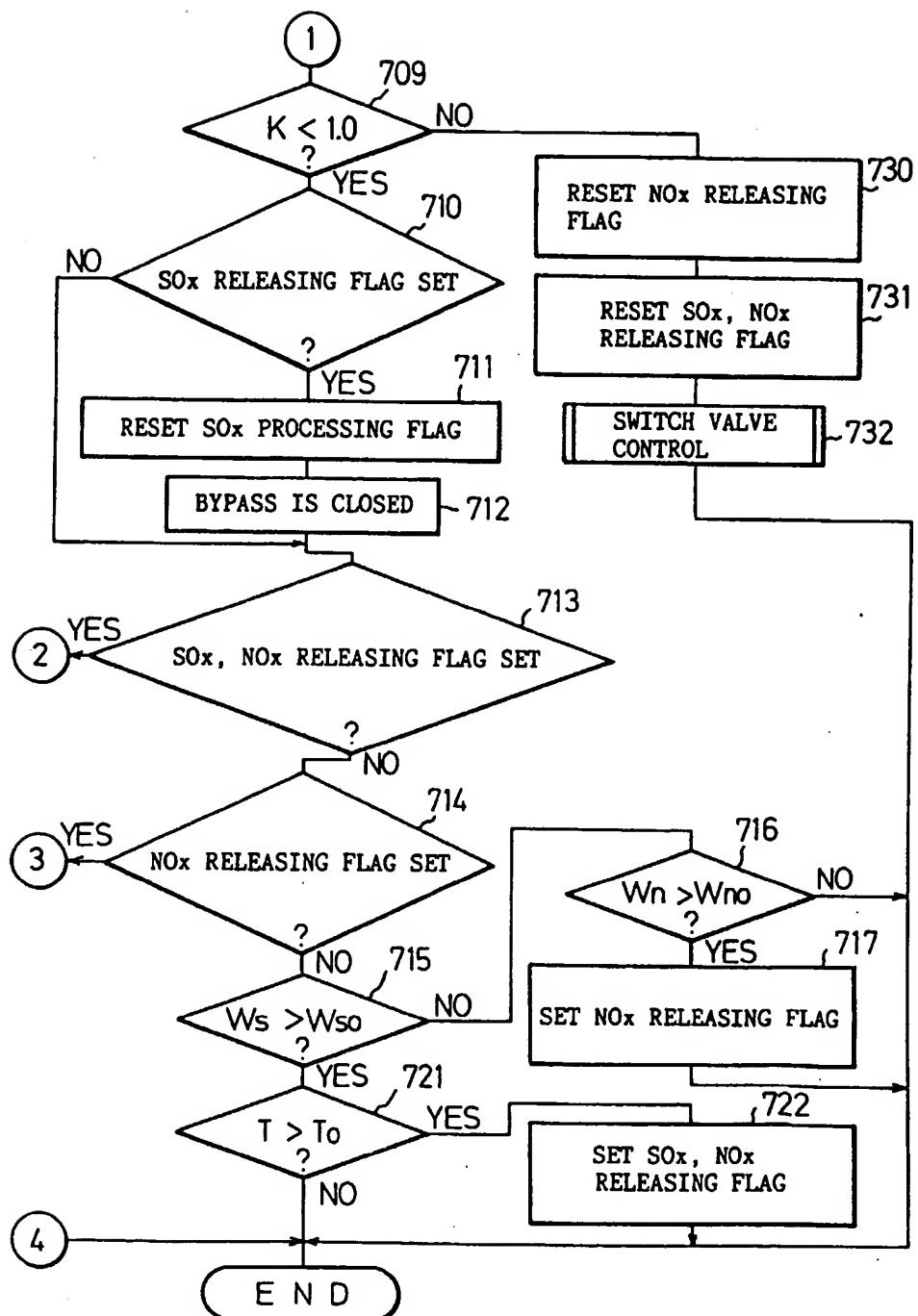


Fig. 35C

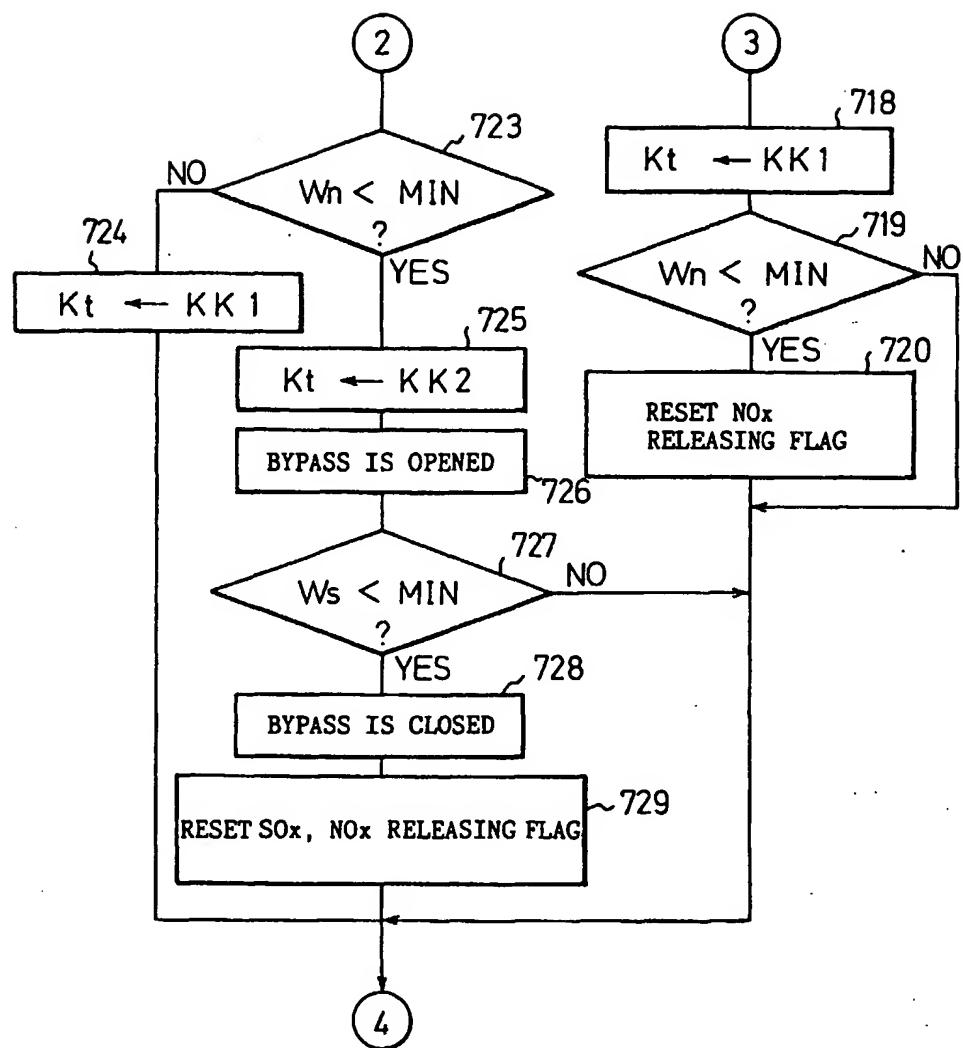


Fig. 35D

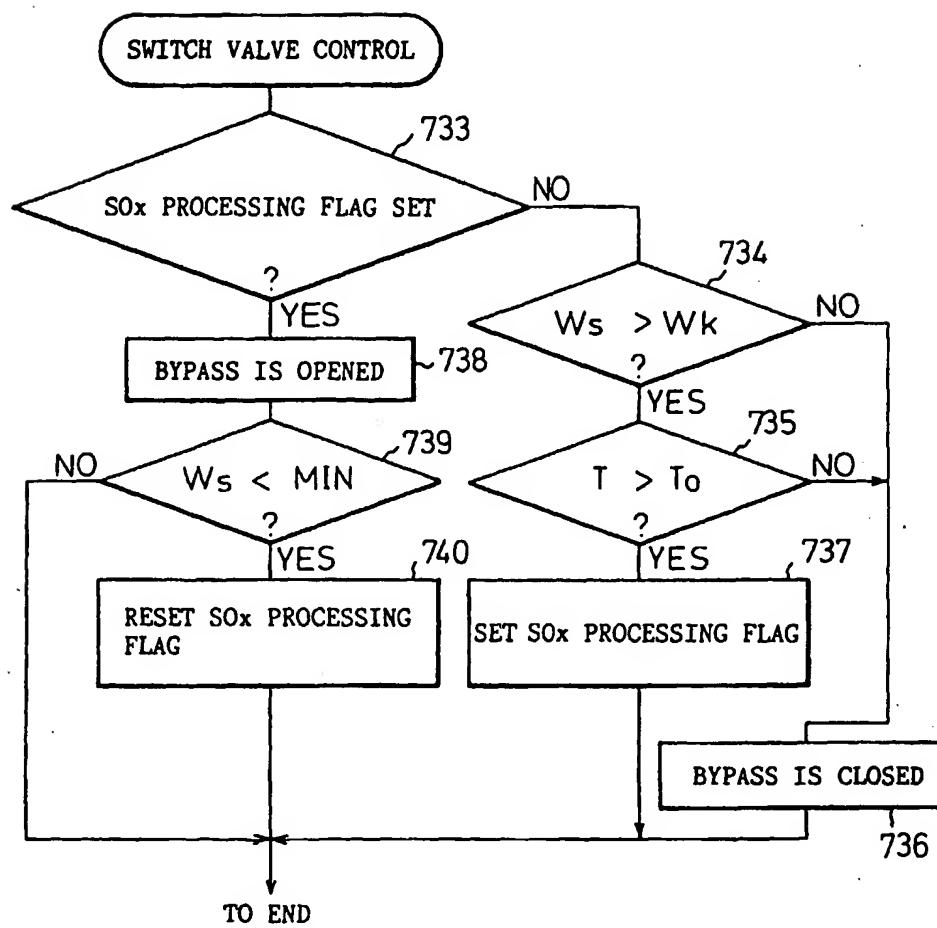


Fig.36

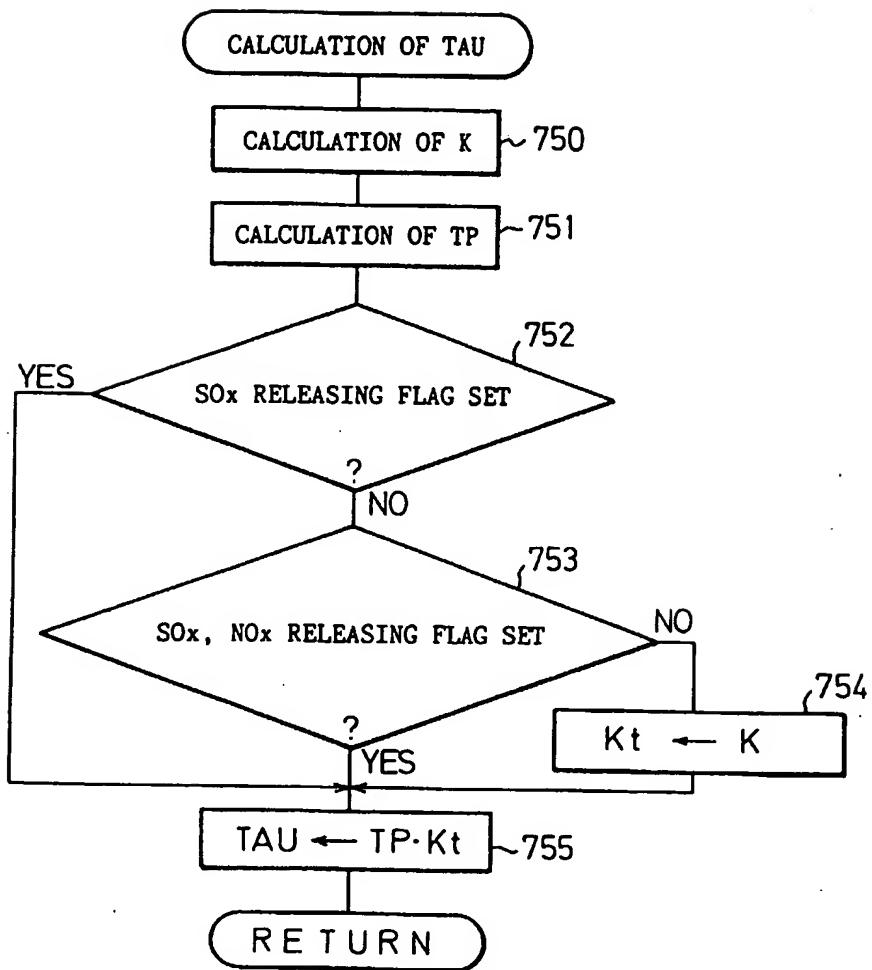


Fig. 37A

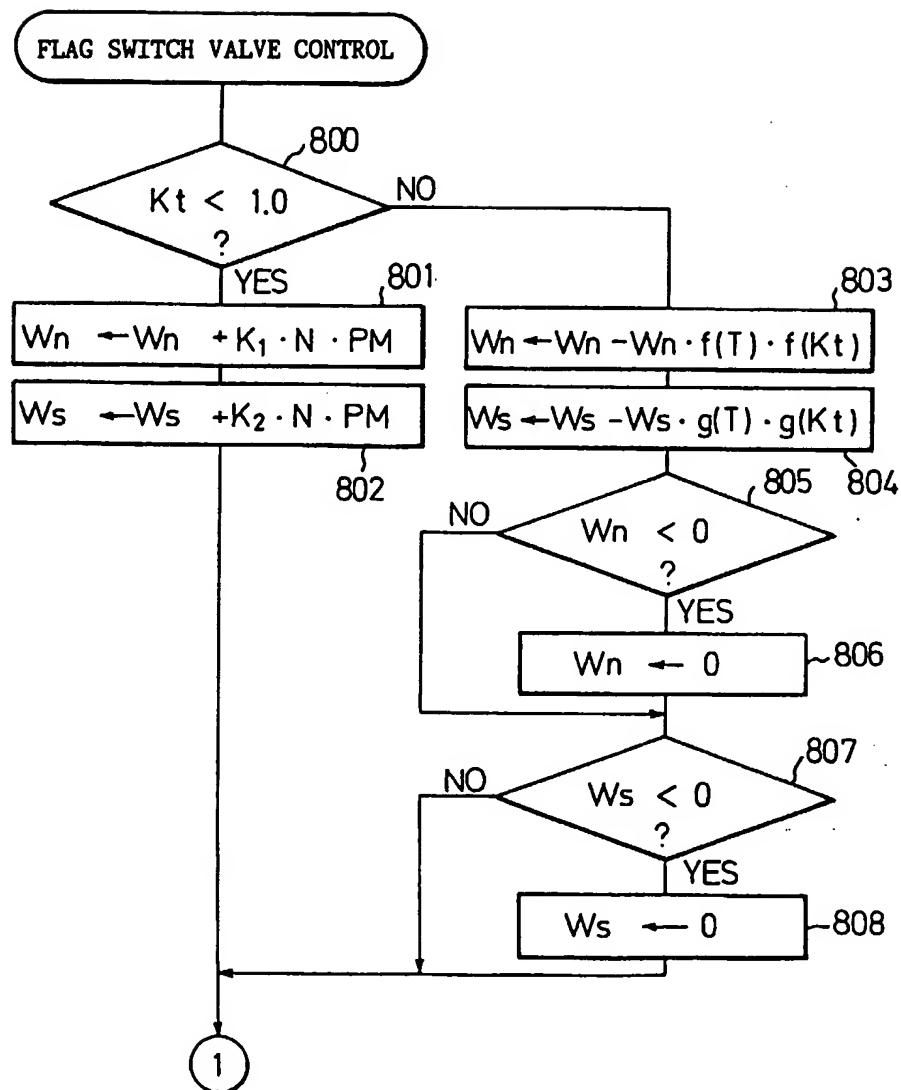


Fig. 37B

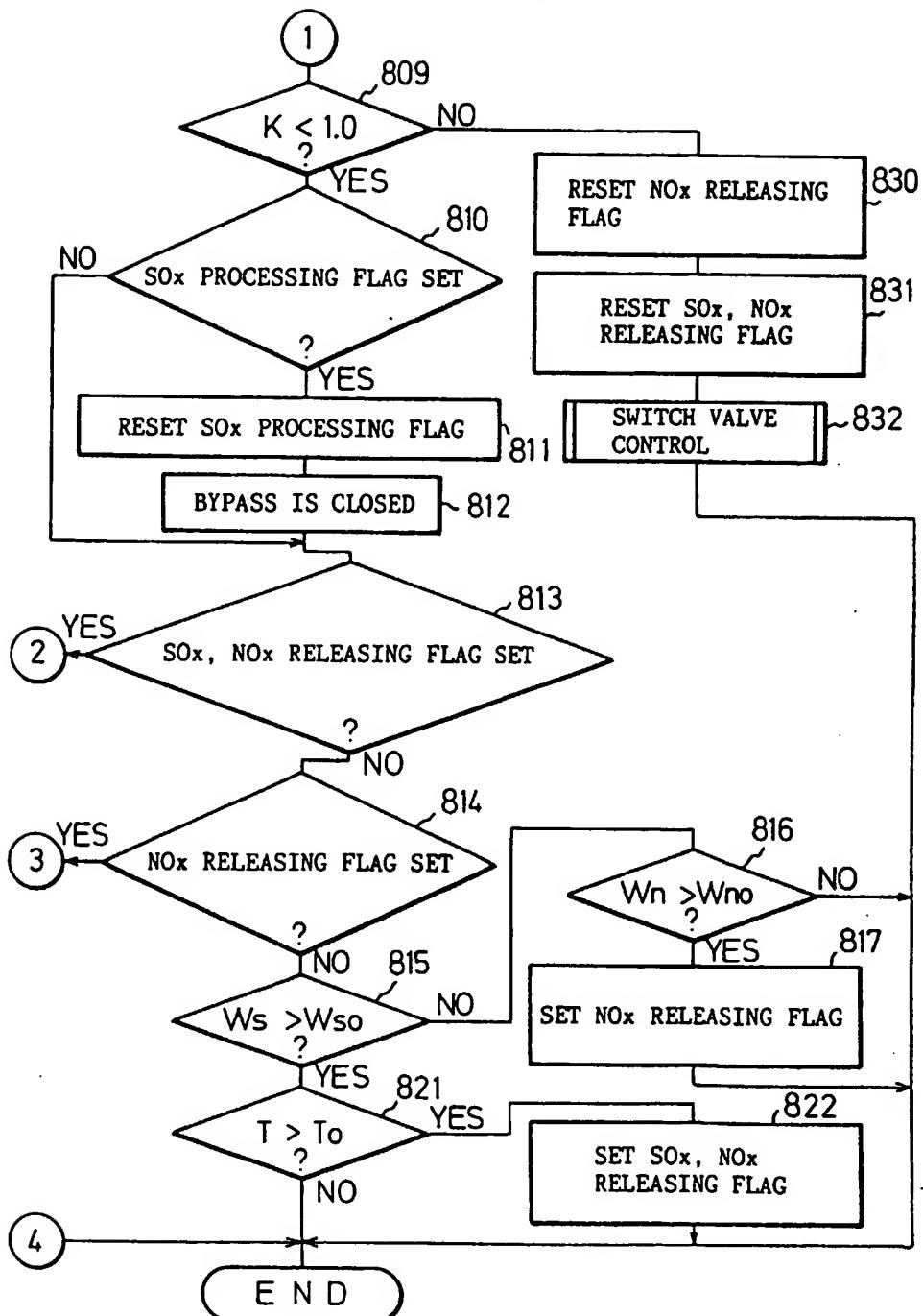


Fig. 37C

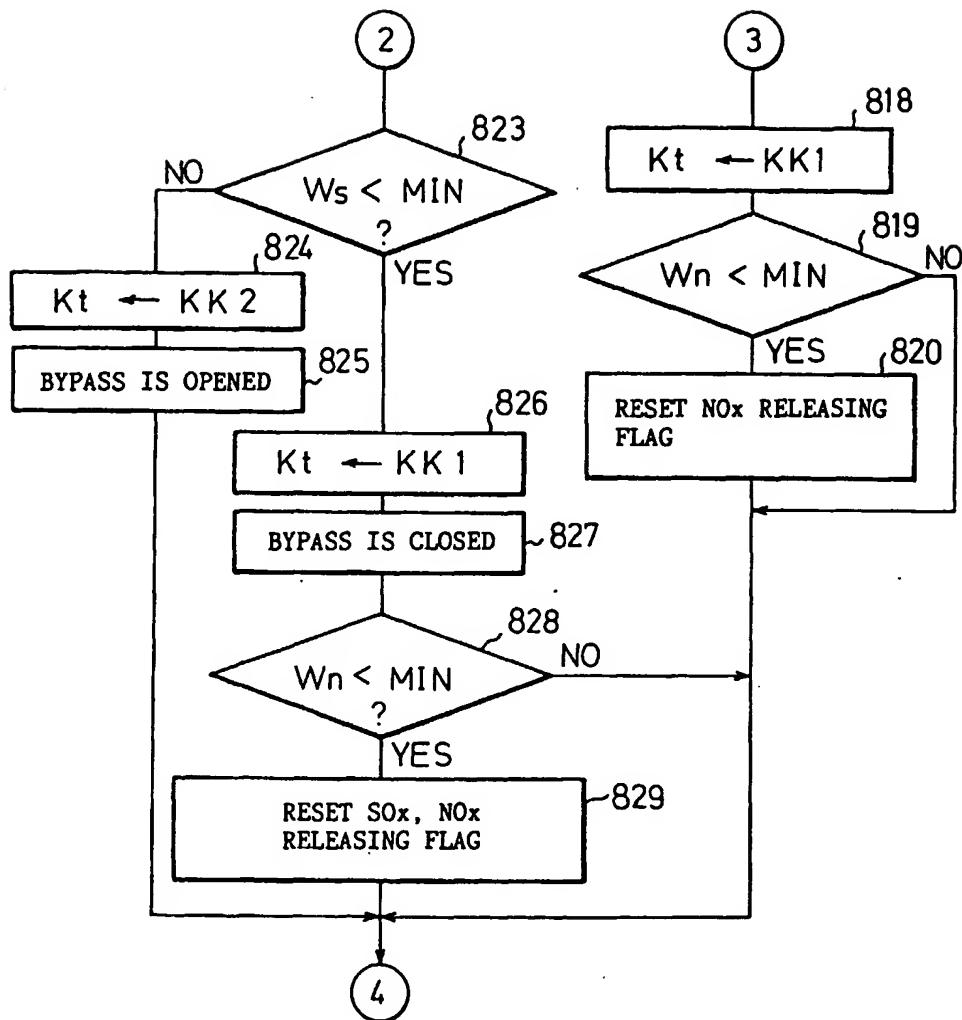


Fig. 37D

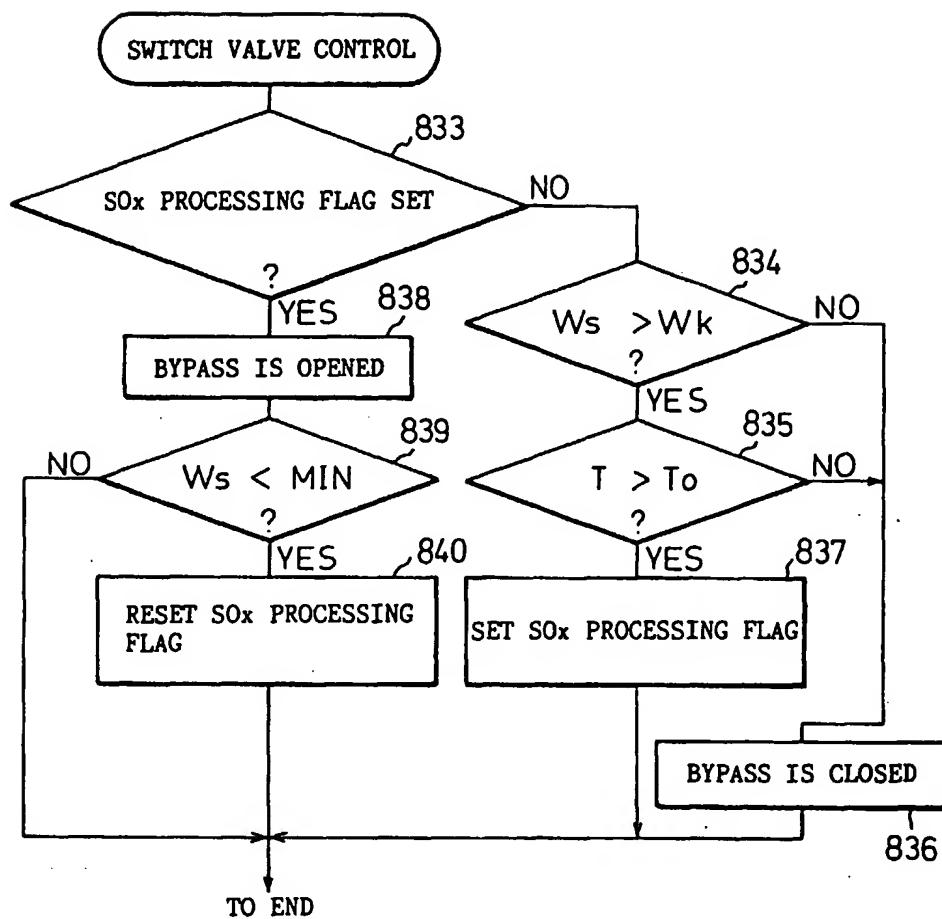


Fig. 38

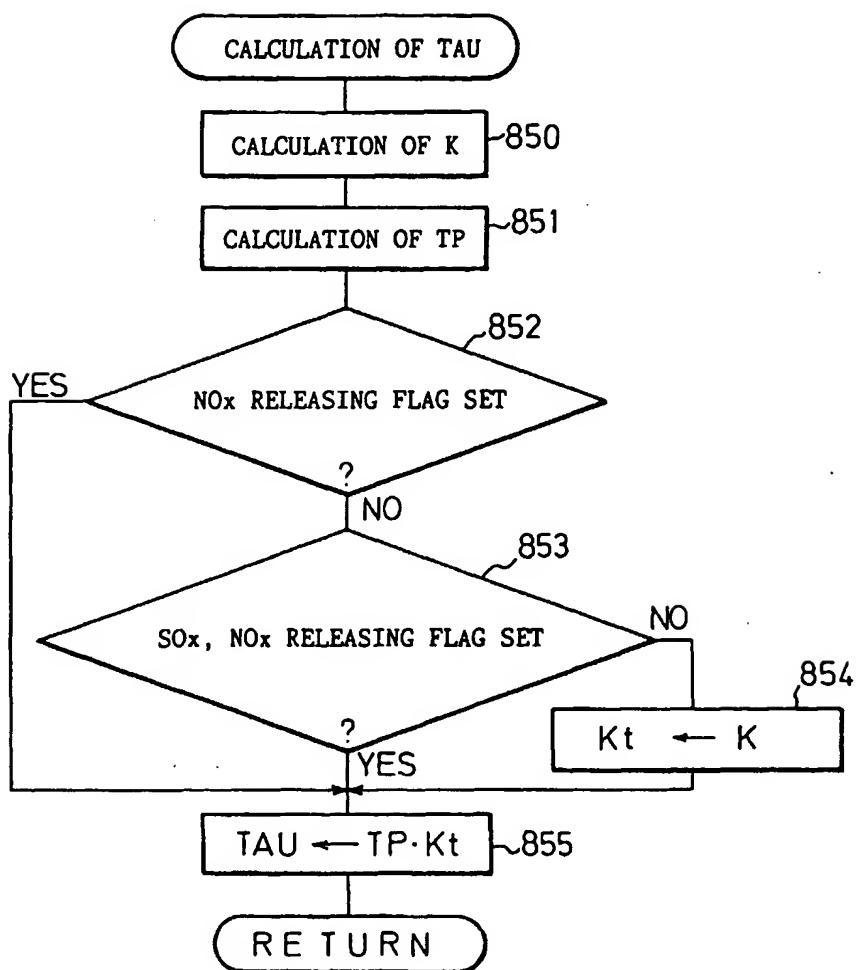


Fig.39A

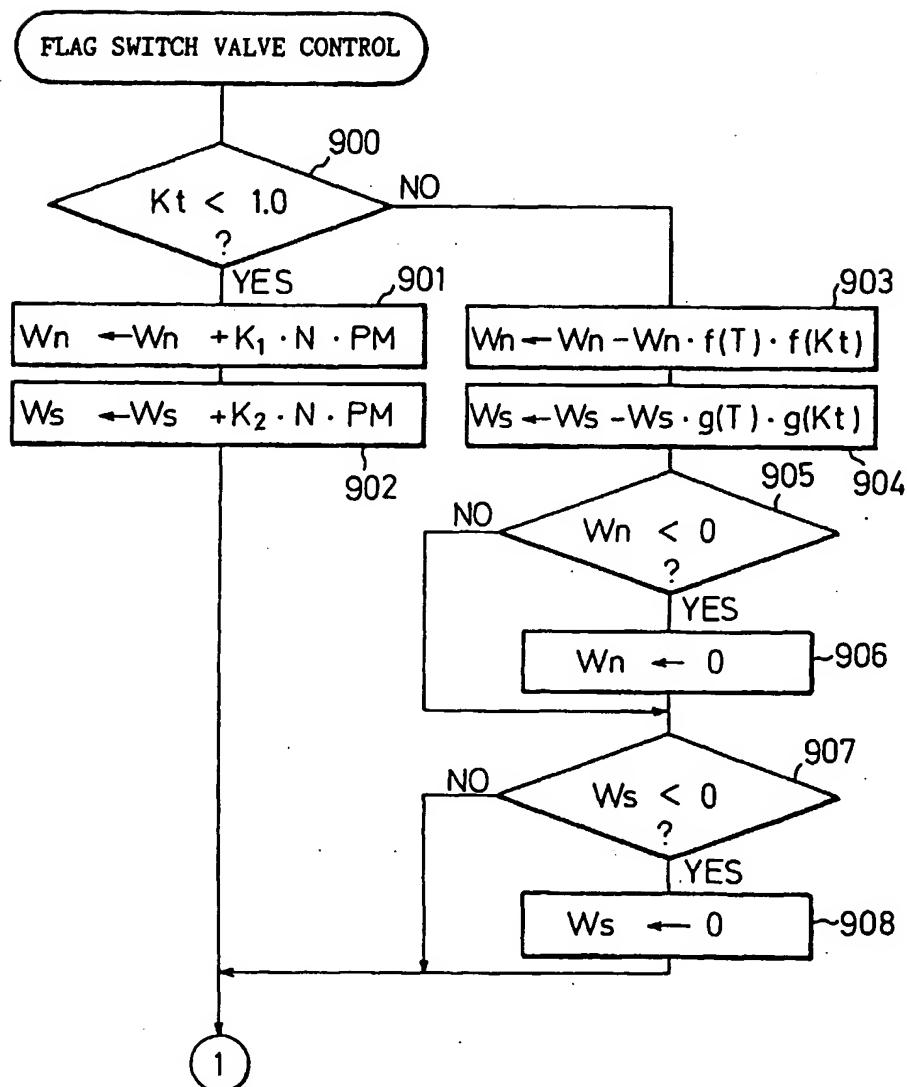


Fig. 39B

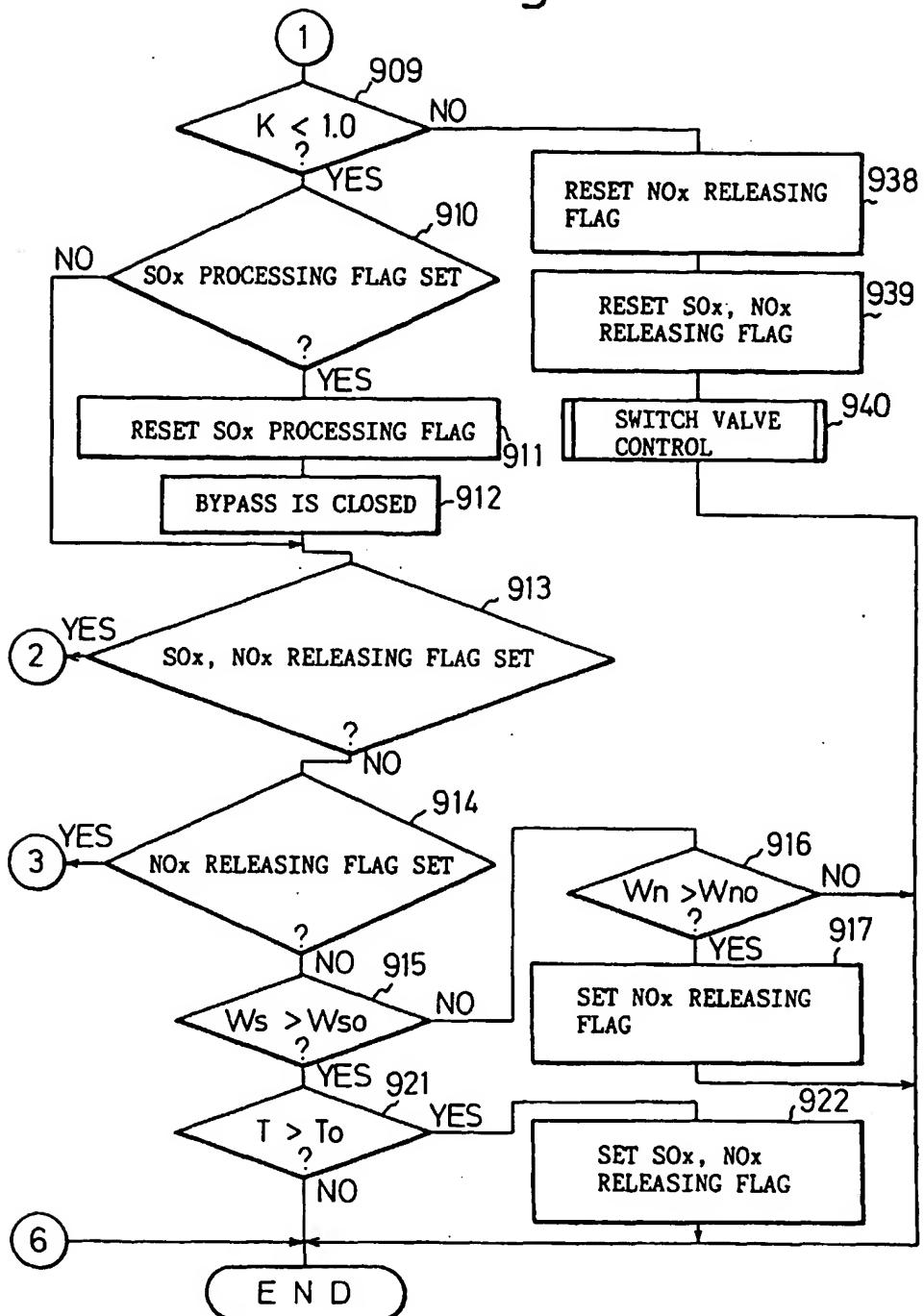


Fig.39C

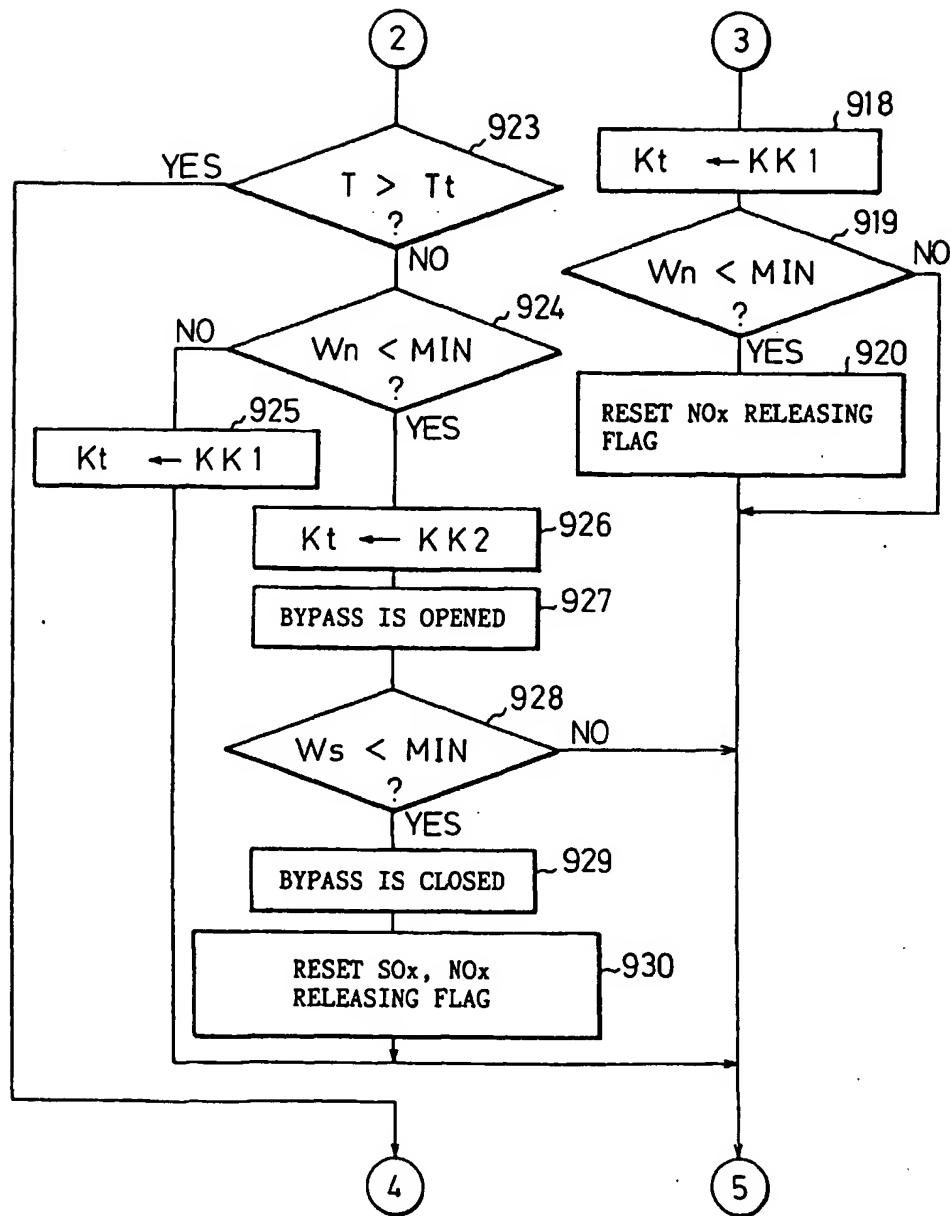


Fig. 39D

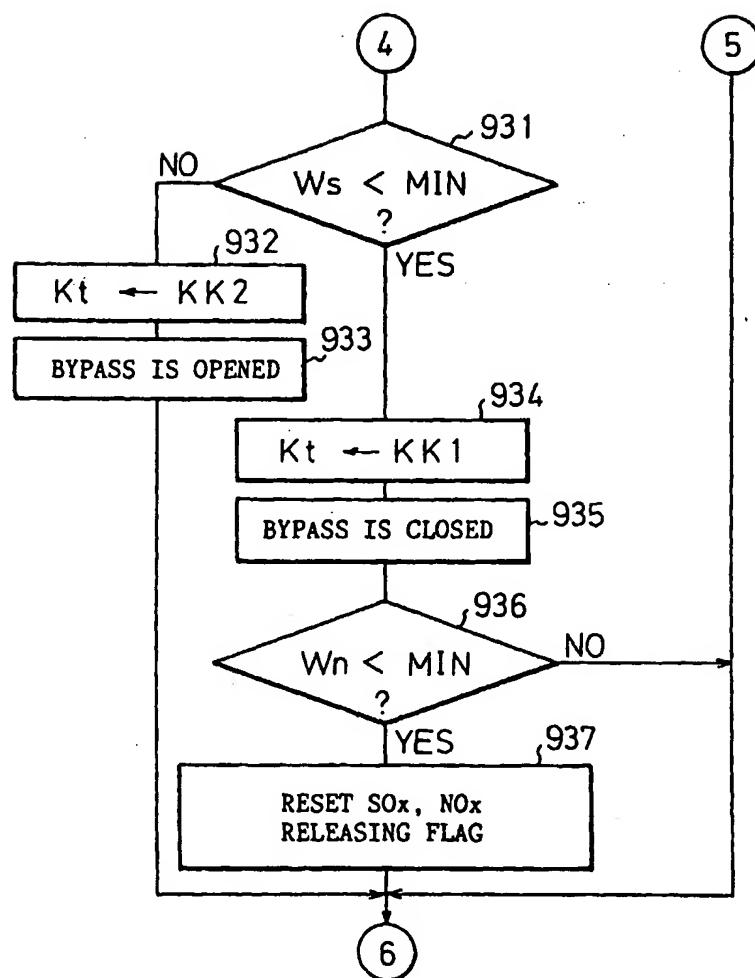


Fig. 39E

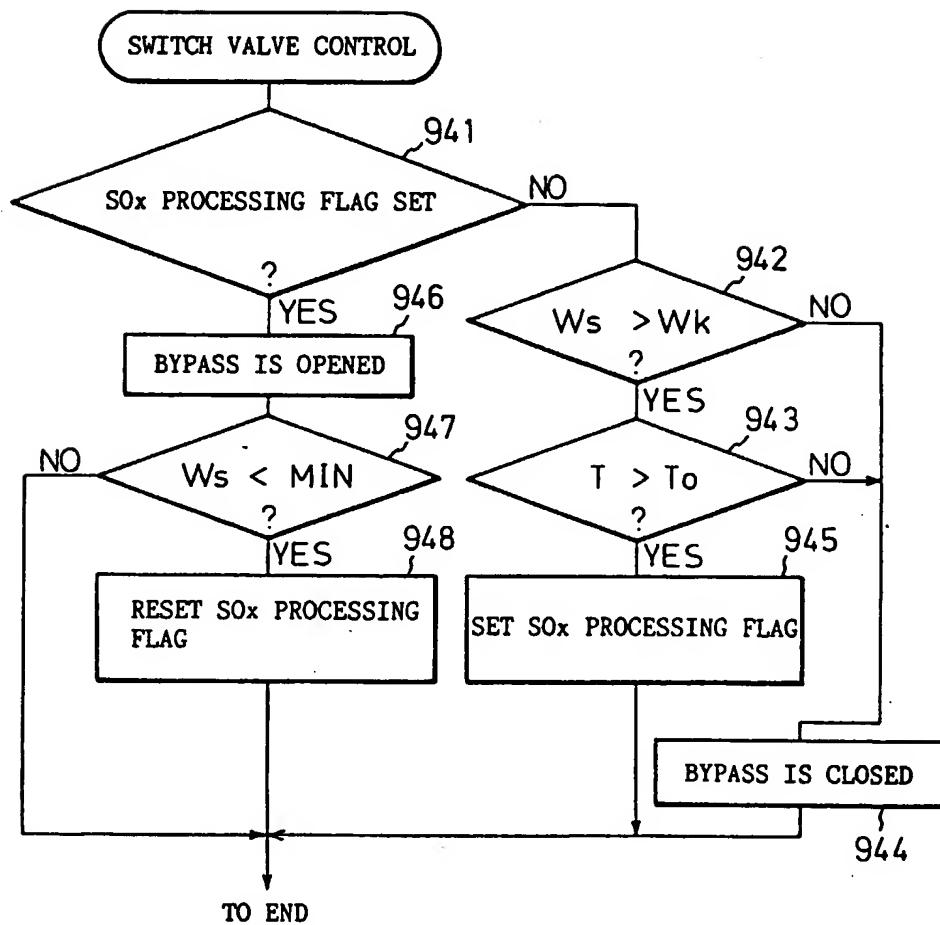
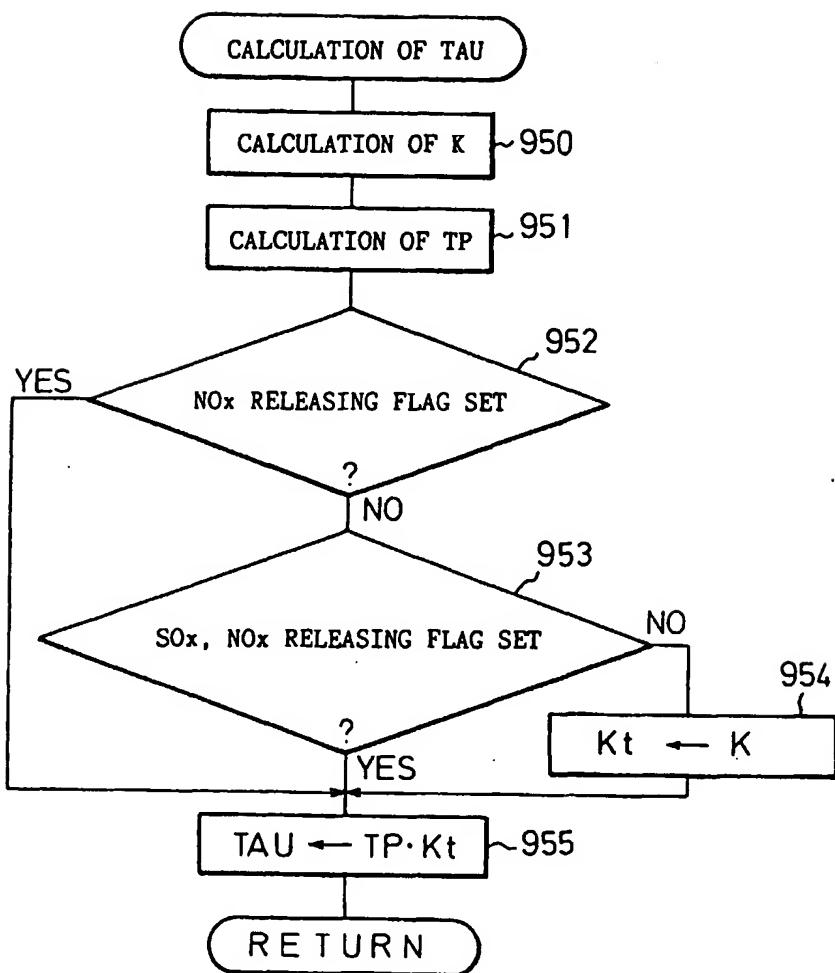


Fig.40



LIST OF REFERENCES

- 16 ... exhaust manifold**
- 17 ... exhaust pipe**
- 18 ... SO_x absorbent**
- 19 ... NO_x absorbent**
- 24 ... bypass passage**
- 27 ... switch valve**